TECHNICAL REPORT NO. 3-680

IMPROVED BEACH MATTING FOR U. S. NAVY AMPHIBIOUS OPERATIONS, ENGINEER TESTS JANUARY-AUGUST 1964

by

S. G. Tucker

June 1965

Sponsored by

Bureau of Yards and Docks
Department of the Navy

and

Marine Corps Landing Force Development Center
Quantico, Va.

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
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ARMY-MRC VICKSBURG, MISS.

FOREWORD

This report describes engineer tests that were conducted for the development of an improved beach matting material which can be placed by hand by Naval Amphibious Construction Battalions/Marine Corps Shore Party Battalions to improve the movement of wheeled vehicles across medium- to steep-sloped sand beaches, including the dune areas. The improved beach matting study was authorized by the Chief, Bureau of Yards and Docks, Department of the Navy, Washington, D. C., in a letter dated 9 August 1961 to the Director, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., through the Chief of Engineers, Department of the Army, Washington, D. C., subject "Improved Beach Matting; Assignment of R&D Task in Connection with."

Engineer tests reported herein were conducted at WES during the period January to August 1964. Coordination of the test program was accomplished with Capt. M. M. Atkins, Combat Service Support Division, Marine Corps Landing Force Development Center, Marine Corps Schools, Quantico, Va., and Mr. O. B. Crumpler, Bureau of Yards and Docks, Washington, D. C.

Engineers of the WES Soils Division who were actively concerned with the planning, analysis, and report phases of this study were Messrs. W. J. Turnbull, W. G. Shockley, A. A. Maxwell, W. L. McInnis, and S. G. Tucker. This report was prepared by Mr. Tucker.

Col. Alex G. Sutton, Jr., CE, and Col. John R. Oswalt, Jr., CE, were Directors of the WES during the time of this field study and preparation of this report. Mr. J. B. Tiffany was Technical Director.

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SUMMARY

Engineer tests were conducted on three surfacing materials which were placed on an unsurfaced, sloped, sand test section to determine their suitability for improving the trafficability of dune areas of sand beaches for wheeled vehicles. Materials tested were: (a) woven, 1-1/8-in.-square-mesh nylon netting weighing 0.26 psf in sections 20 ft wide and 60 ft long, (b) woven, 4-in.-square-mesh polypropylene cargo netting weighing 0.35 psf in sections 16 ft wide and 60 ft long, and (c) woven wire steel mat weighing about 2.3 psf in sections 10 ft 8 in. wide and 50 ft long. The first two test items were selected as a result of previous field tests conducted at Onslow Beach, N. C., during 1963; the woven wire steel mat is used currently by the U. S. Navy during amphibious operations and was included in these tests for comparative purposes.

The sand test section used consisted of loose, dry sand constructed on a slope of 10 percent. Each surfacing material was placed on the sand test section without side or end anchorage and subjected to traffic with an M38A1 jeep and trailer, M37 truck and trailer, and M54 truck and trailer to simulate the loads and tire-inflation pressures of wheeled vehicles used currently by Fleet Marine Forces. The maximum total load required to be transported across each test item represented the estimated tonnage to be unloaded from two landing ships, tank (LST's).

Results of these tests indicated the following:

a. No test vehicle with trailer was capable of ascending the unsurfaced sand section.

b. All vehicles and trailers simulating traffic from the unloading of two LST's successfully negotiated the sloped sand test section surfaced with the polypropylene cargo netting and the woven wire mat.

c. All vehicles and trailers simulating traffic from the unloading of one LST successfully negotiated the sloped sand test section surfaced with the nylon netting; but during simulated traffic from a second LST, the jeep and trailer became immobilized on the third pass.

d. The order in which traffic was applied to the test items

influenced, to some extent, the performance of the materials in improving trafficability of the sand section. As an example, the M54 truck and trailer were unable to ascend the nylon netting-surfaced sand test section unless the netting was first seated in the sand by lighter vehicle traffic.

e. Hand placement rates of 1200, 1152, and 187 sq ft per man-hour were attained with the nylon netting, polypropylene netting, and wire mat, respectively. These rates were affected considerably by the time required to make end connections for the various items.

f. The woven wire mat was too heavy for placement up a sand slope of 10 percent with a crew of six men.

g. The two nettings were capable of reuse after tests, but approximately 15 to 20 percent of the wire mat was damaged by vehicle traffic.

h. Slippage of vehicle wheels occurred on the two nettings but not on the wire mat. Since the test items were not anchored at the upper end of the sand section, the ends were displaced longitudinally down the slope under the action of the vehicle wheels.

i. The wheels of test vehicles pulled both nettings in along the unanchored sides to conform to resulting ruts.

j. The extent and depth of rutting were less severe with the wire mat than with the two nettings. Maximum depths of ruts under the nettings were as much as 10 to 12 in., whereas most of the rutting under the mat did not exceed 4 to 5 in.

k. After vehicles of one LST have been unloaded, the nettings should be pulled from the rutted sand subgrade, stretched, and repositioned before the second LST is unloaded.

l. The woven polypropylene cargo netting was the most satisfactory surfacing material tested considering (1) ease of placement by hand, (2) placement rate, (3) performance without anchorage under vehicle traffic simulating the tonnage unloaded by two LST's, and (4) capability for recovery and reuse.

Based on results of this study, it is recommended that modifications be made in the cargo netting to provide a more rapid method for connecting ends of sections, and to increase the width to about 22 ft to provide needed additional area for vehicle passage and to assist in confining sand along the sides of the ruts. Obviously, the use of end and side anchorage would further improve the performance of the material. The modified netting should be evaluated during naval amphibious landings to determine its suitability for improving the trafficability of sand beaches and dune areas.

IMPROVED BEACH MATTING FOR U. S. NAVY AMPHIBIOUS OPERATIONS
ENGINEER TESTS, JANUARY-AUGUST 1964

PART I: INTRODUCTION

Background

1. Present plans for amphibious landings envision U. S. Navy craft discharging military vehicles across beaches at high tide. Since most, if not all, of the foreshore of the beach will be inundated at this time, only the sand area that extends above the point of high tide will be traversed by vehicles. This area to be crossed is called the backshore and "dunes," and consists of loose, dry sand that ruts easily under heavily loaded wheeled vehicles and impedes the movement of traffic across the beach. At the present time, a woven wire (steel) beach mat is used by shore party battalions to improve movement of vehicles across sand beaches. These mats are heavy and cumbersome, and they must be transported and placed by trucks equipped with special placement frames. The mats become jammed frequently in the frames, and considerable troop effort is required to place the mats. A lightweight matting or material is desired, to replace the woven wire beach mat, which can be joined in sections and hand-placed by field troops.

Previous Investigations

2. Based on discussions held at the Bureau of Yards and Docks (BuDocks) in December 1961 and subsequent information received from the Commander, Amphibious Force, U. S. Atlantic Fleet, Norfolk, Va., a proposal was prepared by the U. S. Army Engineer Waterways Experiment Station (WES) for improved beach matting tests. The vehicle selected for use in these initial tests was the M135 2-1/2-ton 6x6 cargo truck with single tandem wheels, a gross load of 17,500 lb, and a tire-inflation pressure of 30 psi. The proposal for the tests and the use of this vehicle were approved by BuDocks in April 1962. A number of materials were investigated, and engineer tests of some were conducted on a sand section with a 10 percent slope using the M135 vehicle. Upon conclusion of these tests in March 1963, four of the most promising materials were procured and tested at Onslow

Beach, N. C.* These materials included (a) a vinyl-coated nylon fabric weighing 0.2 psf, (b) a neoprene-coated nylon fabric weighing 0.43 psf, (c) a woven nylon netting weighing 0.26 psf, and (d) a polypropylene cargo netting weighing 0.35 psf. The sides of each nylon fabric (a and b, above) were anchored by means of nylon rope running through grommets in the fabric edges and secured to lightweight arrowhead anchors driven into the sand, but the two nettings (c and d, above) were not anchored.

3. Results of these tests indicated that in regard to facility of placement and overall performance the two nettings were more satisfactory than the two fabrics, particularly since considerable effort and time had been expended in anchoring the sides of the fabrics to improve their performance. It was also ascertained during the tests that dual-wheeled vehicles used currently by Fleet Marine forces are heavier than the M135 vehicle used in the initial engineer tests and have higher tire-inflation pressures; in addition, almost all the vehicles that come ashore pull trailers. Based on this additional vehicle information and the results of tests on materials at Onslow Beach, the WES recommended that:

- a. The woven nylon netting and the cargo netting be considered the most satisfactory materials used as improved beach matting at Onslow Beach.
- b. Additional engineer tests be conducted on these items at the WES to determine the effects of mixed vehicle traffic with heavier loads and higher inflation pressures.
- c. Specifications be prepared for the material that proves most satisfactory in these engineer tests.

Objective of This Investigation

4. The objective of the investigation reported herein was to evaluate and compare the performance of the two nettings tested at Onslow Beach with that of the woven wire beach mat presently used in amphibious landing operations by the Marine Corps when placed on a sloped loose-sand subgrade

* U. S. Army Engineer Waterways Experiment Station, CE, Improved Beach Matting Tests at Onslow Beach, N. C., 20-25 May 1963, Miscellaneous Paper No. 4-600 (Vicksburg, Miss., September 1963).

and subjected to mixed vehicle traffic (including trailers) with heavy loads and high tire-inflation pressures. It was recognized that the use of anchors along the sides and ends of the surfacing materials would improve their performance, but it was requested by the Navy that all anchorage be omitted from these tests in order that a minimum construction time and effort could be achieved.

PART II: TEST MATERIALS, VEHICLES, AND METHODS

Woven Nylon Netting

5. The nylon netting weighed about 0.26 psf and was fabricated by machines that wove type A, No. 84, continuous nylon filament twine into a 1-1/8-in.-square-mesh pattern. The resistance of the netting to abrasion and sunlight was improved by treatment with a medium No. 20 asphalt emulsion. Sections of the netting were black, 20 ft wide and 60 ft long, weighed 309 lb, and arrived at WES folded into compact bundles that had a volume of 24 cu ft. A 1/2-in.-diam nylon lashing rope was provided to secure the ends of the sections together. The nylon netting was designated item 1 for these tests, and photograph 1 illustrates the construction of the netting.

Woven Cargo Netting

6. The cargo netting weighed 0.35 psf and consisted of 5/8-in.-diam polypropylene ropes that were interwoven into a 4-in.-square-mesh pattern to prevent slippage of one rope over the other. Sections of the netting were yellow, 16 ft wide and 60 ft long, weighed 335 lb, and arrived at WES folded into compact bundles that had a volume of 36 cu ft. A 5/8-in.-diam lashing rope was provided to join the ends of the sections. The cargo netting was designated item 2, and photograph 2 shows the construction of the netting.

Woven Wire Mat

7. The wire mat weighed about 2.3 psf and consisted of No. 8 gage (0.162 in.) steel wire which was basket woven (over and under) into 14-in.-wide and 10-ft-8-in.-long continuous wire bands. As mentioned in paragraph 1, the mat was designed for transportation and placement by trucks equipped with special overhead frames. A detailed drawing of the mat is shown in plate 1. The mat was received at the WES in bundles (photograph 3) that weighed 1214 lb, had a volume of 26.5 cu ft, and

provided enough material to surface an area 50 ft long and 10 ft 8 in. wide. All mat used for this study was received from the Marine Corps Supply Center, Albany, Ga.

Test Vehicles

8. Vehicles and trailers used for this study (photograph 4) were as follows:

- a. M38A1 jeep and M100, 1/4-ton trailer.
- b. M37, 3/4-ton, 4x4 truck and M101, 3/4-ton trailer.
- c. M54, 5-ton, 6x6 truck and 2-W-M101, 1-ton trailer.

Photograph 5 shows the method of loading each vehicle with lead weights and steel ballast to simulate traffic loads. Detailed loading data are shown in plates 2-4. The gross loads and tire-inflation pressures were as follows:

Vehicle	Gross Load, lb	Tire-Inflation Pressure, psi
M38A1 jeep	2,780	28
M100 1/4-ton trailer	1,005	28
M37 truck	7,440	45
M101 3/4-ton trailer	2,595	45
M54 truck	30,600	70
M101 1-ton trailer	3,200	55

Method of Testing

9. Wheeled vehicle traffic simulated the tonnage and volume of traffic discharged across sand beaches by landing ships, tank (LST's) during U. S. Navy amphibious landings. In placement of traffic on the sloped test section, vehicles were stopped at the lower end of the section, shifted into low gear, low range, and driven up the section at a steady speed. Several drivers were used for each vehicle to simulate different driver techniques for steering and operation of vehicles. Vehicles were steered so that traffic remained in the same track or tracking area, and at no time were vehicles permitted to accelerate or gain momentum prior

to moving onto the test section. Since it was assumed that vehicles transported by two LST's would be discharged across the beach matting roadway, the selection of the number of passes or trips that each vehicle made on the test section was based on information furnished by the Commander, Amphibious Force, U. S. Atlantic Fleet, Norfolk, Va. The order of unloading, number of trips made by each vehicle and trailer, total weight of vehicles and trailers, and the total load transported across each of the test items during this study were as follows:

Vehicle and Trailer	No. of Passes	Total Weight of Vehicle and Trailer, lb	Total Load Transported Across Test Section, lb
	Vehicles Discharged by First LST		
M38A1 jeep and M100, 1/4-ton trailer	10	3,785	37,850
M37, 3/4-ton, 4x4 truck and M101, 3/4-ton trailer	10	10,035	100,350
M54, 5-ton, 6x6 truck and 2-W-M101, 1-ton trailer	8	33,800	270,400
Total load discharged across each test item by first LST			408,600
	Vehicles Discharged by Second LST		
M38A1 jeep and M100, 1/4-ton trailer	21	3,785	79,485
M37, 3/4-ton, 4x4 truck and M101, 3/4-ton trailer	19	10,035	190,665
M54, 5-ton, 6x6 truck and 2-W-M101, 1-ton trailer	4	33,800	135,200
Total load discharged across each test item by second LST			405,350

The overall total load transported across each of the test items on the sand test section for purposes of this study was 813,950 lb. However, because of immobilization of the M38A1 jeep on its third pass over the nylon netting, the total load transported across this material was only 742,035 lb (see paragraph 27).

Construction of Test Section

10. The site selected for construction of the test section was a soil area with a slope of 10 percent. An area 22 ft wide, 100 ft long, and 30 in. deep was excavated. The excavation was then sealed with a prime coat of asphalt and filled with sand by means of a mobile crane. The sand was spread and sloped by hand (photograph 6) to minimize compaction during spreading and final grading. The sand used was classified as a poorly graded, nonplastic sand (SP). Classification and gradation data for the sand are shown in plate 5.

11. In previous investigations* conducted by the WES that concerned sand beaches, gradation data were obtained for beaches in the continental United States and in overseas areas. A comparison of gradation curves for these beaches and the sand test section is shown in plate 6. These data indicate that the sand test section can be considered representative of beaches in Guam, Luzon, Hawaii, and Oahu; however, beaches in France, such as Suscinio and La Turballe, are coarser grained and those in Kwajalein, the Yuma dune area, and at Onslow Beach, N. C., are finer grained. A general view of the sloped sand test section prior to traffic tests is shown in photograph 7.

Data Obtained

12. The following information and pertinent field data were obtained before, during, and after vehicle traffic tests: moisture content and density; in-place sand bearing strength determinations (airfield cone penetrometer readings and corresponding CBR's); profiles and permanent surface deformations; time required for surfacing the test section with each test item; and visual observations of the performance of the test items under the action of vehicle traffic. These data were supplemented

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* U. S. Army Engineer Waterways Experiment Station, CE, Trafficability of Soils; Tests on Coarse-Grained Soils With Self-Propelled and Towed Vehicles, 1956 and 1957, Technical Report No. 3-240, Fifteenth Supplement (Vicksburg, Miss., June 1959) and Beach Stabilization Tests of Landing Mats and Prefabricated Membranes, Technical Report No. 3-592 (Vicksburg, Miss., February 1962).

by still photographs (shown in this report) and movies (on file at WES, BuDocks, and Marine Corps Landing Force Development Center).

PART III: TESTS AND RESULTS

Traffic Tests on Unsurfaced Sand Test Section

13. Tests were conducted on the unsurfaced sand test section to determine the ability of the test vehicles to traverse sand beaches and to provide a basis for evaluating and comparing the capability of each test item to improve the trafficability of sand beaches for wheeled vehicles. The sand was raked and the surface smoothed prior to operations with each vehicle.

14. When the M38A1 jeep with trailer moved onto the sand test section, slight slippage of both front and rear wheels of the jeep was observed. As the vehicle continued up the section, slippage of all jeep wheels increased until complete slippage of the front wheels occurred. When this occurred, the rear wheels dug and settled into the sand subgrade until the jeep was immobilized. The jeep traveled 33 ft up the test section before it was immobilized (photograph 8), at which time the rear differential and springs were in contact with the sand subgrade. Ruts caused by the front wheels were 4 to 6 in. deep, and ruts caused by the rear wheels were 7 to 8 in. deep. Photograph 9 shows the ruts caused by immobilization of the jeep.

15. At first there was no apparent slippage of the wheels of the M37 truck as it moved (with trailer) onto the test section. However, as the M37 moved up the test section, slippage of all wheels occurred almost instantaneously; this caused a violent jerking motion of the wheels, and all forward movement of the vehicle stopped, after which the vehicle was considered immobilized. The M37 traveled 27 ft up the test section before it was immobilized, as shown in photograph 10. Although the differentials and springs were not in contact with the sand subgrade when the vehicle was immobilized, ruts caused by the front and rear wheels were 6 to 8 and 9 to 11 in. deep, respectively.

16. Wheels of the M54 truck began to slip slightly as the vehicle started up the test section. When the wheels of the trailer reached the sand subgrade, complete slippage of all M54 wheels occurred, and this caused a violent jerking motion of the wheels and immobilization of the

vehicle about 29 ft up the test section. At the time the M54 was immobilized (photograph 11), the rear differential and springs were in contact with the sand subgrade. Ruts caused by the front wheels were 9 to 10 in. deep, and ruts caused by the rear wheels were 12 to 13 in. deep. Photograph 12 shows the ruts caused by immobilization of the M54. Upon completion of traffic tests on the unsurfaced sand test section, the sand was raked smooth before test items were placed on the section.

Placement of Test Items on Sand Test Section

Woven nylon netting (item 1)

17. Placement of nylon netting began at sta 1+00 and continued up the section to sta 0+00 (see plate 7). Sections of the item were received from the manufacturer folded in burlap bags as shown in photograph 13. The folded netting was first positioned at the approximate center of the lower end of the test section and unfolded up the section (photograph 14). After placement along the center line, the netting was unfolded and stretched across the test section (photograph 15). Additional sections of the netting were placed in the same manner, and the ends of the sections were lashed together with a 1/2-in.-diam nylon rope, as shown in photograph 16, to form a continuous net surfacing. Photograph 17 shows test item 1 on the test section prior to vehicle traffic tests. Each section of netting was unfolded, positioned, and stretched on the test section by a crew of six men in approximately 5 min. A total time of 30 min was required to place three sections (each 20 by 60 ft) of the netting and lash the ends of the sections together. Thus, approximately one-half of the time required for placement of the netting was devoted to lashing the ends of the sections together. The netting was hand-placed without any anchorage at the rate of 1200 sq ft per man-hour.

Woven cargo netting (item 2)

18. Each section of the cargo netting was removed from a burlap bag, as shown in photograph 18, placed in the approximate center of the lower end of the test lane, and unrolled up the test section. As placement of the cargo netting continued up the test section, the ends of the sections were lashed together with a 5/8-in.-diam polypropylene rope to form a

continuous surfacing (see photograph 19). Test item 2 on the sand test section prior to vehicle traffic tests is shown in photograph 20. Each section of the cargo netting was unrolled, positioned, and stretched on the test section by a crew of six men in approximately 4 to 6 min. A total time of 25 min was required to place three sections (each 16 by 60 ft) and lash the ends of the sections together. Thus, approximately 10 min of the total placement time were required to lash the ends of the sections together. The cargo netting was hand-placed without any anchorage at the rate of 1152 sq ft per man-hour.

Woven wire beach mat

19. Bundles of the wire beach mat were positioned with a forklift at the lower end of the test section, as shown in photograph 21. A crew of six men then removed the mat from the bundle, as shown in photograph 22, and pulled the mat up the test section. The crew was able to place only about one-half of the bundle of mat on the test section before the weight of the mat became too much for the crew to handle. Therefore, the mat was removed from the test section and replaced in the bundle. Then all bundles of mat were transported with the forklift to the upper end of the test section, and placement of the mat began at sta 0+00 and continued to sta 1+00 (see plate 7). A total time of 60 min was required for the crew to place three sections of the mat on the sand test section. Each section was 10 ft 8 in. wide and approximately 50 ft long. Ends of the sections were connected with connecting rods 5 ft 7 in. long, as shown in detail No. 6 of plate 1. Two rods were required to connect the full width of the mat, with one rod being inserted at each side of the mat and threaded through the ends of the sections. The threading of the connecting rods through the mat required approximately 30 min, which accounts for 50 percent of the total placement time. The mat was hand-placed without any anchorage at the rate of 187 sq ft per man-hour. Although it was realized that the beach mat is normally placed by means of a truck equipped with a spreading frame, as shown in photograph 23, the mat was placed by hand in this study for comparison with the other test items. The wire beach mat on the test section prior to vehicle traffic tests is shown in photograph 24.

Traffic Tests on Surfacing Materials

Initial pass of vehicles on nylon netting (item 1)

20. Initial traffic was placed on the nylon netting with the M38A1 jeep with trailer. As the vehicle proceeded up the test section, the edges or sides of the netting were pulled in toward the wheels, and slack in the netting was accumulated in rolls approximately 3 to 4 in. high at regular intervals by the pulling action of the vehicle wheels. The condition of the netting after the first pass of the jeep with trailer is shown in photograph 25. No slippage of vehicle wheels was noted, although ruts 3 to 4 in. deep were formed in the sand subgrade. The uppermost net section was moved down a distance of 1 ft along the longitudinal slope of the test section by the pulling action of the vehicle wheels.

21. After the initial pass of the jeep with trailer, the netting was removed, the sand subgrade was raked smooth, and the netting was repositioned on the test section. Then the M37 truck with trailer was driven across the netting. Passage of this vehicle pulled the netting in at the sides and matted it beneath the wheels. Rolls of slack approximately 5 to 6 in. high accumulated in the netting at regular intervals along the test section. Ruts 5 to 7 in. deep were made in the sand subgrade, but no slippage of vehicle wheels was observed. Photograph 26 shows the condition of item 1 after the initial pass of the M37 with trailer. The uppermost section of the netting was moved down a distance of 29 ft along the longitudinal slope of the test section by the pulling action of the vehicle wheels.

22. After the initial pass of the M37 with trailer, the netting was removed, the sand subgrade smoothed, and the netting repositioned on the test section. Then the initial pass of the M54 truck with trailer was conducted. As the wheels of the vehicle crossed the netting, they pulled it in from the sides and matted it in the ruts caused by the vehicle. After the netting was matted beneath the wheels, slack was pulled into it along the longitudinal axis of the test section. More and more slack was pulled into the netting as the vehicle moved up the test section until the slack was balled up beneath the wheels, and complete slippage occurred. When

complete slippage occurred, the jerking motion of the wheels pulled sand from beneath and from along the sides of the netting and deposited the sand on the netting. When the vehicle became immobilized 51 ft up the test section, the rear differential and springs were in contact with the netting, as shown in photograph 27. The sand subgrade was rutted to depths of 8 to 10 and 12 to 14 in., respectively, by the front and rear wheels of the vehicle. Photograph 28 shows the condition of item 1 after the removal of the immobilized M54 from the test section. The uppermost section of netting was moved down a distance of 35 ft along the longitudinal slope of the test section by the pulling action of the vehicle wheels.

23. The initial pass of each test vehicle with trailer across item 1 indicated that the nylon netting was adequate for wheel loads and tire-inflation pressures of the M38A1 jeep and M37 truck with trailers, but not for wheel loads and tire-inflation pressure of the M54 truck with trailer. The average CBR of the sand subgrade during initial passes of vehicle traffic on the netting was equal to approximately 1 or less. Based on these limited observations, it was believed that unless the netting was permitted first to seat in the sand subgrade, and thereby help to confine and consolidate the sand beneath the wheels of the lighter test vehicles, the M54 truck with trailer would not be able to traverse the sand test section. Therefore, mixed vehicle traffic was conducted on the nylon netting by first applying all traffic with the M38A1 jeep, then all traffic of the M37 truck, followed by traffic with the M54 truck.

Mixed traffic on
nylon netting (item 1)

24. Simulated vehicle traffic of first LST. After the initial-pass tests discussed in paragraphs 20-23, the sand test section was smoothed and the nylon netting was placed on it. Ten passes each of the M38A1 jeep and M37 truck with trailers were then made in that order on the netting. There was no tendency for the wheels of the vehicles to slip, even though the netting soon became buried in the ruts caused by the tires. Traffic pulled the netting in at the sides and caused slack in it at irregular intervals along the test section. Vehicle wheels caused ruts approximately 4 to 5 in. deep. The condition of the netting after traffic with the jeep and M37 but before traffic of the M54 is shown in photograph 29.

25. On its initial pass, the M54 truck with trailer pulled all netting that remained at the sides of the ruts (caused by prior traffic) beneath the vehicle wheels and buried it in enlarged ruts caused by the dual tires of the M54. During the first five passes of the M54, the depth of ruts in the sand subgrade increased with each pass of the vehicle; but after the fifth pass, the depth of ruts remained constant until eight passes had been completed. The condition of item 1 and the sand test section after mixed vehicle traffic simulating the unloading of the first LST is shown in photograph 30. The maximum depth of ruts in the sand subgrade at this time was 11 to 12 in., as shown in photograph 31. Airfield cone penetrometer readings, which were obtained in the sand test section at sta 0+25, 0+50, and 0+75 before and after vehicle traffic of one LST had been placed on item 1, are shown in plates 8-10. These and subsequently mentioned penetrometer readings were obtained along the center line of the test item before traffic tests and in ruts caused by vehicle wheels after traffic tests. Cross sections of the test section were obtained before and after traffic and are shown in plate 11.

26. Simulated vehicle traffic of second LST. Before traffic was placed on the netting to simulate the unloading of the second LST, the netting was pulled out of the ruts caused by the first LST traffic, stretched, and positioned over the ruts. As vehicle traffic of the second LST was placed on the netting, it was noted that the ground clearance of the M37 and M54 trucks was such that the front and rear differentials did not drag across the netting. The ground clearance of the M38A1 jeep was such that the front differential did not drag, but the rear differential did and a large ball of netting was gathered and pushed forward immediately in front of the rear wheels. During the third pass of the jeep, the netting became entangled in the rear wheels and caused immobilization of the vehicle, as shown in photograph 32.

27. After the immobilized jeep was removed from the test section, the netting was straightened and vehicle traffic with the M37 and M54 trucks and trailers was continued until 19 passes of the M37 and 4 passes of the M54 had been placed on item 1. Photograph 33 shows the test section after vehicle traffic of two LST's (less 19 passes of the jeep and trailer) and after a total of 742,035 lb had been transported across it. The

uppermost mat section was moved 35 ft down the slope of the test section by the traffic of the two LST's. Cross sections of the test section obtained after vehicle traffic of two LST's are shown in plate 11, and they indicate that the maximum depth of ruts in the sand subgrade was 12 to 13 in. Upon completion of vehicle traffic tests, airfield cone penetrometer readings were obtained (plates 8-10). Moisture content and density determinations are shown in table 1.

Initial pass of vehicles
<u>on cargo netting (item 2)</u>

28. The initial pass of vehicle traffic on item 2 was conducted with the M38A1 jeep with trailer, which caused 3- to 4-in.-deep ruts in the sand subgrade and pulled the netting in slightly at the sides. The wheels of the jeep did not wrinkle or pull slack into the netting as the vehicle traversed the test section (photograph 34). After the initial pass of the jeep, one pass was conducted with the M37 truck with trailer. The wheels of the M37 pulled the netting in at the sides and rutted the sand subgrade to a depth of approximately 4 to 5 in. The wheels of the vehicle did not wrinkle or pull slack into the netting (photograph 35). Following the passage of the M37 truck with trailer across item 2, the initial pass of the M54 truck with trailer was conducted. All netting that remained at the sides of the ruts (caused by previous traffic of the M38A1 jeep and M37 truck) was pulled into the ruts caused by the dual wheels of the M54 truck. Very little slack was pulled into the netting by the wheels of the vehicle as it crossed the test section, even though the sand subgrade was rutted to a depth of 7 to 9 in. (photograph 36).

Mixed traffic on
<u>cargo netting (item 2)</u>

29. <u>Simulated vehicle traffic of first LST.</u> After initial passage of test vehicles, the subgrade was smoothed and the cargo netting placed on it. In contrast to mixed traffic on the nylon netting, traffic on the cargo netting consisted of passes of the three vehicles in train. Ten passes each of the M38A1 jeep and M37 truck and eight passes of the M54 truck with trailers were placed on item 2 to simulate the unloading of the first LST. After five passes by each test vehicle, the netting in the ruts had become buried in the sand. As traffic continued, the netting that

covered the area of the test section between the ruts moved back and forth as each vehicle crossed the section, and this seesaw action caused the netting to become buried just beneath the surface of the sand. Slight slippage of vehicle wheels was observed during vehicle traffic of the first LST. The cargo netting after vehicle traffic of the first LST is shown in photograph 37. At this time, the maximum depth of ruts in the sand subgrade was 8 to 9 in., as shown in photograph 38. Airfield cone penetrometer readings obtained in the sand test section at sta 0+25, 0+50, and 0+75 before and after traffic are shown in plates 12-14. These readings were obtained as described in paragraph 25. Cross sections were obtained before and after traffic and are shown in plate 15.

30. Simulated vehicle traffic of second LST. Upon the completion of vehicle traffic tests that simulated the unloading of the first LST and the collection of pertinent data, the cargo netting was pulled out of the ruts caused by previous vehicle traffic, stretched, and positioned over the ruts. Item 2 prior to vehicle traffic of the second LST is shown in photograph 39. Traffic was placed on item 2 in the same manner as that described in paragraph 29. The ground clearance of all test vehicles was such that they were able to negotiate the test section without dragging the springs and/or differentials on the netting. The condition of the test section and netting after initial passes of all three test vehicles with trailers is shown in photograph 40. As vehicle traffic continued, the netting was pulled in at the sides and buried in ruts caused by the wheels of the vehicles. The netting that covered the sand test section between the ruts moved back and forth as each vehicle moved across the test section. This seesaw movement of the netting caused it to become buried just beneath the surface of the sand. To simulate vehicles unloaded by the second LST, 21 passes of the M38A1 jeep with trailer, 19 passes of the M37 truck with trailer, and 4 passes of the M54 truck with trailer were made across the netting. Photograph 41 shows item 2 after vehicle traffic of the second LST and after a total of 813,950 lb had been transported across it. The maximum depth of ruts in the sand subgrade was 9 to 10 in. at this time (see photograph 42). Airfield cone penetrometer readings were obtained (described in paragraph 25) after vehicle traffic of the second LST and are shown in plates 12-14. Cross sections of the sand test section are shown

in plate 15. Moisture content and density determinations before and after traffic are shown in table 2.

Initial pass of
vehicles on wire mat

31. The initial pass of vehicle traffic on the wire mat was conducted with the M38A1 jeep with trailer. As the jeep moved up the test section, the wheels pulled each 14-in.-wide panel of the mat down the slope and caused the mat to buckle. The buckling of the mat was not considered severe since the panels were not permanently bent or deformed. Areas of the mat became buried in the sand during the initial pass of the jeep (photograph 43). When the initial pass of the M37 truck with trailer was conducted on the mat, again it was seen that the mat panels were pulled down the slope by the vehicle wheels. The buckling of the mat panels was more severe under the wheels of the M37 than under the wheels of the jeep. Permanent buckling and bending of an individual panel of the mat occurred near sta 0+15 (see plate 7). The buckle in the panel was 9 in. high and occurred across the full width of the mat, as shown in photograph 44. Although additional panels of the mat buckled beneath the wheels of the M37, they were not bent or permanently deformed. A general view of the mat after the initial pass of the M37 is shown in photograph 45. After the initial pass of the jeep and M37, the M54 truck with trailer was driven onto the mat. During the initial pass of the M54, its front wheels pulled slack in the mat and caused the panels to buckle. As the mat buckled, the rear wheels of the truck crimped and crushed the buckled panels. Panels at sta 0+10, 0+15, 0+35, and 0+50 were bent and deformed by the initial pass of the M54 (see plate 7). Photograph 46 shows buckled and deformed panels caused by wheels of the M54 during its initial pass on the test section. Rutting of the subgrade, which was hardly identifiable after the initial passes of the jeep and M37, was clearly defined beneath the mat after passage of the M54. The mat was bent and stretched in the area traversed by the wheels of the M54, and end curl of the panels was noted throughout the length of the test section. The condition of the mat after the initial pass of the M54 truck with trailer is shown in photograph 47.

Mixed traffic on wire mat

32. Simulated vehicle traffic of first LST. Vehicle traffic

simulating unloading of the first LST was then conducted on the mat with it in the condition just described, and very little if any additional slack was caused by the wheels of the jeep and M37. However, each time the M54 crossed the test section, the wheels of the truck pulled, buckled, deformed the mat at irregular intervals along the test section. Rutting became more pronounced beneath the mat, and end curl of the panels increased appreciably as vehicles crossed the mat. Ten passes of the M38A1 jeep, 10 passes of the M37 truck, and 8 passes of the M54 truck, all with trailers, were made as described in paragraph 29. There was no slippage of vehicle wheels on the mat, even though areas of the mat were buried in the sand subgrade. After vehicle traffic of the first LST, the sand subgrade was rutted to a depth of 8 to 9 in. The condition of the mat at this time is shown in photograph 48. Airfield cone penetrometer readings obtained in the sand subgrade before and after traffic are shown in plates 16-18. Cross sections of the mat and sand subgrade are shown in plate 19.

33. Simulated vehicle traffic of second LST. After vehicle traffic of the first LST was completed and pertinent data were obtained, attempts were made to stretch and straighten the buckled and bent panels of the mat. Since hand labor was inadequate, vehicles were hooked to the mat, and tension applied to the sides of the panels. This method of straightening the panels with vehicles also proved unsatisfactory, and vehicle traffic of the second LST was conducted on the mat with it in essentially the same condition as that which existed after vehicle traffic of the first LST was completed. During the vehicle traffic of the second LST, the M54 truck stalled while moving up the test section. When the driver restarted the vehicle and it began to move up the section, it was noted that the pulling action of the wheels when starting from a stopped position on the mat was much more severe than that exerted during normal passage of the vehicle across the mat. As initial movement of the wheels occurred on the mat, panels of the mat were moved down the slope, slack accumulated beneath the wheels, and severe bending of the panels occurred. This action occurred even though a slow, steady movement of the vehicle was maintained up the test section. Vehicle traffic used to simulate the unloading of the second LST consisted of 21 passes of the M38A1 jeep, 19 passes of the M37 truck, and 4 passes of the M54 truck, all with trailers, during

which a total of 813,950 lb was transported across the test section. Although rutting of the sand subgrade did not increase appreciably (11 to 12 in. compared with 8 to 9 in. after traffic of first LST), the buckling, bending, and end curl of the panels were severe, as shown in photograph 49. The undercarriage of the jeep dragged as the mat buckled beneath the wheels, but the mat was not damaged and there was no tendency for the mat to become entangled in the wheels of the vehicle. The maximum depth of ruts in the subgrade was 11 to 12 in. at one location after vehicle traffic of the second LST, but the average depth was less than 6 in. The condition of the mat at this time is shown in photograph 50. Airfield cone penetrometer readings were obtained after traffic tests and are shown in plates 16-18. Cross sections of the mat and sand subgrade are shown in plate 19. Moisture content and density determinations are shown in table 3.

PART IV: DISCUSSION OF RESULTS

Sand Test Section

34. The gradation of the sand subgrade used for the test section was not representative of coarse sand beaches located in some areas of the United States and overseas, but approximated an average condition for most medium- to fine-grained sand beaches for which data are available. The average CBR of the sand subgrade prior to vehicle traffic was less than 1 for a depth of 24 in. and thus provided loose sand that was rutted easily by test vehicles. Although the dune areas of most sand beaches possess low bearing strengths at depths of 0 to 12 in., the bearing strengths at depths of 13 to 24 in. are generally greater than those found at the shallower depths. The test section used in this study was covered with tarpaulins during periods of inclement weather to prevent rains from entering the sand subgrade and thus maintain a loose, dry sand condition. When attempts were made to negotiate the unsurfaced sand test section with the test vehicles, all vehicles were immobilized. During vehicle traffic tests on the surfacing materials, it was found that the vehicles caused ruts 3 to 9 in. deep in the sand on the initial trip across the test section. As additional passes of the vehicles were made on the test items, the depth of ruts in the sand increased at a slow, steady rate to approximately 12 in. Additional passes of the test vehicles did not cause the rut to deepen. Therefore, it is believed that the sand test section constructed for this investigation provided an expedient means for simulating most characteristics of loose, dry sand found in dune areas of sand beaches.

Woven Nylon Netting, Item 1

35. Test results indicate that no particular training or skill is required for the rapid placement of the nylon netting, as an inexperienced crew of six men placed the netting rapidly on the sand test section. Although 50 percent of the total placement time was devoted to lashing the ends of the sections together, the netting was placed at the rate of 1200 sq ft per man-hour. Traffic tests caused wrinkling and slack in the netting

and buried it in the rutted subgrade, but the netting was easily straightened and repositioned on the test section. The netting was too light and closely woven for loads and tire pressures of the M54 truck with trailer unless the netting was first seated in the sand by lighter vehicle traffic. The netting is considered adequate for vehicle traffic of the M38A1 jeep and M37 truck, both with trailers, provided that traffic with the M54 truck with trailer is not placed on the netting until after all passes of the jeep and M37 have been completed. Mixed vehicle traffic of all test vehicles on the netting caused immobilization of the M38A1 jeep with trailer because of inadequate ground clearance which occurred during the simulated unloading of the second LST. The netting, when compared with the other two test items, must be considered inadequate for improving the trafficability of sand beaches for the volume and tonnage of mixed vehicle traffic unloaded by two LST's.

Cargo Netting, Item 2

36. The ability of the open-weave cargo netting to seat rapidly into the sand subgrade prevented vehicle wheels from pulling and accumulating excessive slack in the netting. Once the netting became buried in the rutted subgrade, very little if any movement of the netting down the slope of the test section was caused by vehicle traffic. The dual wheels of the M54 truck pulled all netting at the sides of the tracking area into the ruts and buried the netting in the sand. It is believed that a netting somewhat wider than the sections used for these tests should be specified. The wider sections of netting will help to prevent loose sand at the sides of the ruts from flowing into the ruts and covering the netting. A netting approximately 22 ft wide should be adequate to permit approximately 2 ft of the netting to remain at each side of the tracking area (i.e. outside of the ruts) after the netting has seated in the sand subgrade. Even though the netting was placed by a crew of six men at the rate of 1152 sq ft per man-hour, the lashing together of the ends of the sections required approximately 40 percent of the total placement time. An expedient means for connecting the ends of the netting together is needed to improve the placement rate. The elastic nature of the polypropylene ropes permitted the

netting to adhere and conform to the rutted surface of the sand subgrade without failure or permanent deformation of the netting. The capability of the netting for reuse was illustrated during these tests when it was removed, stretched, and repositioned on the test section after vehicle traffic tests buried it in the sand subgrade. The cargo netting is considered better than the other two test items when such characteristics are compared as: performance beneath wheels of mixed vehicle traffic; capability for rapid placement, recovery, and reuse; and capability for improving the trafficability of sand beaches for the volume and tonnage of vehicles discharged by two LST's.

Woven Wire Beach Mat

37. The mat was not adversely affected by the M38A1 jeep and M37 truck with trailers. The jeep pulled very little slack in the mat and caused only slight buckling of mat panels. The M37 accumulated sufficient slack in the mat to buckle and bend several panels of the mat. Traffic with the M54 truck was the most severe as on each pass the vehicle pulled, buckled, bent, and deformed the mat at irregular intervals along the length and across the width of the panels. The weight of the M54 caused severe end curl of mat panels and caused panels to move down the slope of the test section. Vehicle traffic of the first LST bent and deformed the mat to the extent that it could not be stretched, straightened, and repositioned on the test section. Although the mat supported the volume and tonnage of mixed vehicle traffic of two LST's, it was so bent and deformed that it was not capable of reuse. Replacement of approximately 15 to 20 percent of the mat panels would have been required before the mat could have been reused.

38. The weight of the mat prevented placement by hand labor from the bottom to the top of the test section, and the placement rate of 187 sq ft per man-hour by a crew of six was the slowest for the three items tested. The connecting together of end panels of mat sections required 50 percent of the total placement time. The threading of connector rods through the rings and helix of each mat panel, as shown in photograph 51, required considerable effort to align the openings of each helix before the rods could be driven through the ends of the panels. This connection feature

of the mat, together with the weight of the mat, accounted for its slow placement rate.

39. During these tests, the mat was placed on a 10 percent slope and considerable slack in and movement of mat panels were caused by wheels of test vehicles. After vehicle traffic of the second LST, the uppermost mat panel had moved a distance of 8 ft down the longitudinal slope of the test section. Based on observations and the performance of the mat in the study, it is believed that slopes steeper than 10 percent will cause excessive buckling and rolling up of the mat panels beneath vehicle wheels and cause immobilization of vehicles with low ground clearances, such as the M38A1 jeep. Anchoring of the mat panels on steep slopes will be necessary to prevent excessive movement of the mat by vehicle wheels.

PART V: SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Results

Woven nylon netting, item 1

40. Specific test results for item 1 are as follows:

a. The nylon netting was hand-placed by a crew of six men at the rate of 1200 sq ft per man-hour.

b. The M38A1 jeep and M37 truck with trailers were not immobilized during the initial pass on item 1, but the M54 truck with trailer was immobilized during the initial pass after traveling a distance of 51 ft up the test section. However, the latter vehicle was able to negotiate the sand test section after ten passes each of the jeep and M37 with trailers.

c. During vehicle traffic of the second LST, the ground clearance of the M37 and M54 trucks was adequate, but the rear differential of the jeep dragged the netting and caused immobilization of this vehicle on the third pass.

d. The uppermost net section was moved down the slope of the test section a distance of 35 ft by the initial pass of the M54, but additional traffic of two LST's did not move it further.

Woven cargo netting, item 2

41. Specific test results for item 2 are as follows:

a. The woven polypropylene cargo netting was hand-placed at a rate of 1152 sq ft per man-hour and seated rapidly in the sand subgrade. The vehicle wheels did not pull slack in the netting or cause excessive movement of the netting down the slope.

b. The elastic characteristics of the 5/8-in.-diam polypropylene ropes allowed the netting to conform to the irregular surface of the rutted sand subgrade.

c. The dual wheels of the M54 truck pulled all netting at the sides of the tracking area into the ruts caused by vehicle wheels and buried the netting in the sand.

d. The netting was pulled easily from the rutted subgrade, stretched, and repositioned for reuse on the test section after vehicle traffic.

e. The netting improved the trafficability of the sand test

section for wheeled vehicle traffic and performed satisfactorily for the volume and tonnage of vehicles discharged by two LST's.

f. Slight slippage of the vehicle wheels occurred during vehicle traffic of the first LST on the netting.

Woven wire mat

42. Specific test results for the woven wire mat are as follows:

a. The woven wire mat had the slowest hand-placement rate of 187 sq ft per man-hour.

b. The panels of mat buckled more severely beneath the wheels of the M37 and M54 trucks than beneath the wheels of the M38A1 jeep.

c. Each pass of the M54 truck with trailer resulted in pulling, buckling, and bending of the panels of the mat. Only occasional bending of the mat panels was caused by the M37 truck, and no bending of panels was caused by the M38A1 jeep.

d. Vehicle traffic of the first LST bent and deformed the mat so that the mat sections could not be straightened.

e. Initial movement of vehicle wheels outside the mat area and then subsequent movement across the mat did not cause as much movement of mat panels down the slope of the test section as when movement of vehicle wheels was initiated on the mat.

f. Mixed vehicle traffic caused end curl of mat panels.

g. After vehicle traffic tests had simulated the unloading of two LST's across the mat, the uppermost panels of the mat had been pulled down the slope of the test section a distance of 8 ft and the mat could not be reused without replacement of 15 to 20 percent of the panels.

h. Slippage of vehicle wheels on the mat did not occur even though areas of the mat were buried in the sand.

Conclusions

43. Based on the results of this investigation, the following conclusions are believed warranted:

a. None of the three test vehicles (with trailers) is capable of ascending an unsurfaced sand beach similar to the test section used in this study.

b. The woven polypropylene cargo netting is the most satisfactory of the three materials tested for mixed vehicle traffic of the volume and tonnage unloaded by two LST's.

c. The woven nylon netting is satisfactory for traffic of the M38A1 jeep and M37 truck with trailers, but is not satisfactory for traffic of the M54 truck with trailer. The netting is too light and closely woven for mixed vehicle traffic of the volume and tonnage unloaded by two LST's.

d. The woven wire mat will support all mixed vehicle traffic of the volume and tonnage discharged by two LST's, but about 15 to 20 percent of the mat panels will be damaged.

e. A slope of 10 percent is approximately the steepest slope on which the woven wire mat can be used without anchoring the mat panels.

f. A rapid means for joining sections of surfacing materials is needed because the time required to join the ends of sections in this study was excessive.

g. After vehicles of one LST have been unloaded across the cargo netting, the surfacing should be pulled from the ruts, stretched, and repositioned on the sand subgrade before the second LST is unloaded.

h. The width of sections of cargo netting should be increased to approximately 22 ft to provide adequate width for steering of vehicles and to prevent loose sand from flowing into the wheel ruts and covering the netting.

i. The woven wire mat is too heavy for rapid hand placement as beach matting.

Recommendations for Future Developments

44. In view of the findings presented in this report, it is recommended that:

a. Modifications be made in the cargo netting to increase the width of the sections and to provide a more rapid means for connecting the ends of sections.

b. Cargo netting be evaluated during U. S. Navy amphibious landings as expedient surfacing on sand beaches to provide roadways for wheeled vehicles across dune areas.

c. Consideration be given to the use of anchors along the sides and ends of matting to improve performance.

Table 1

Moisture Content and Density Determinations

Item 1, Nylon Netting Test Section

Station	Depth, in.	Moisture Content % Dry Weight	Density lb/cu ft
		Before Traffic	
0+25	0-6	2.7	97.7
	6-12	2.9	94.8
	12-18	2.6	97.3
	18-24	2.5	95.2
0+50	0-6	2.2	98.4
	6-12	3.1	95.3
	12-18	2.9	96.9
	18-24	2.0	97.6
0+75	0-6	2.8	98.6
	6-12	2.8	96.0
	12-18	2.0	97.7
	18-24	3.0	97.6
		After Traffic of Vehicles from Two LST's	
0+25	0-6	3.6	107.1
	6-12	2.6	111.0
	12-18	5.8	107.3
	18-24	5.2	104.7
0+50	0-6	1.6	106.2
	6-12	1.5	104.6
	12-18	1.9	104.6
	18-24	2.4	107.4
0+75	0-6	1.7	106.1
	6-12	3.1	106.7
	12-18	2.7	110.6
	18-24	5.6	104.6

Table 2

Moisture Content and Density Determinations

Item 2, Cargo Netting Test Section

Station	Depth, in.	Moisture Content % Dry Weight	Density lb/cu ft
		Before Traffic	
0+25	0-6	1.9	96.9
	6-12	2.7	93.7
	12-18	4.4	94.0
	18-24	3.4	95.2
0+50	0-6	2.2	98.8
	6-12	2.2	93.8
	12-18	3.5	94.0
	18-24	2.8	96.5
0+75	0-6	2.9	95.9
	6-12	3.4	94.9
	12-18	3.4	95.1
	18-24	3.3	95.5
		After Traffic of Vehicles from Two LST's	
0+25	0-6	1.9	107.9
	6-12	3.3	105.8
	12-18	2.9	109.8
	18-24	5.0	104.5
0+50	0-6	1.4	107.5
	6-12	2.2	111.0
	12-18	2.3	107.8
	18-24	4.1	106.0
0+75	0-6	1.5	103.9
	6-12	2.6	109.9
	12-18	2.9	107.8
	18-24	3.8	107.9

Table 3

Moisture Content and Density Determinations

Wire Mat Test Section

Station	Depth, in.	Moisture Content % Dry Weight	Density lb/cu ft
		Before Traffic	
0+25	0-6	2.5	96.6
	6-12	3.4	94.8
	12-18	2.6	94.0
	18-24	2.5	95.4
0+50	0-6	2.4	98.9
	6-12	2.6	95.0
	12-18	2.1	95.4
	18-24	2.3	96.4
0+75	0-6	2.4	96.8
	6-12	2.7	96.2
	12-18	1.7	96.0
	18-24	2.1	95.9
		After Traffic of Vehicles from Two LST's	
0+25	0-6	0.9	113.7
	6-12	3.3	111.2
	12-18	3.2	107.0
	18-24	4.3	106.3
0+50	0-6	0.5	111.6
	6-12	2.4	106.9
	12-18	2.9	108.5
	18-24	2.8	106.2
0+75	0-6	0.3	116.6
	6-12	3.0	108.4
	12-18	3.4	105.6
	18-24	3.8	107.0

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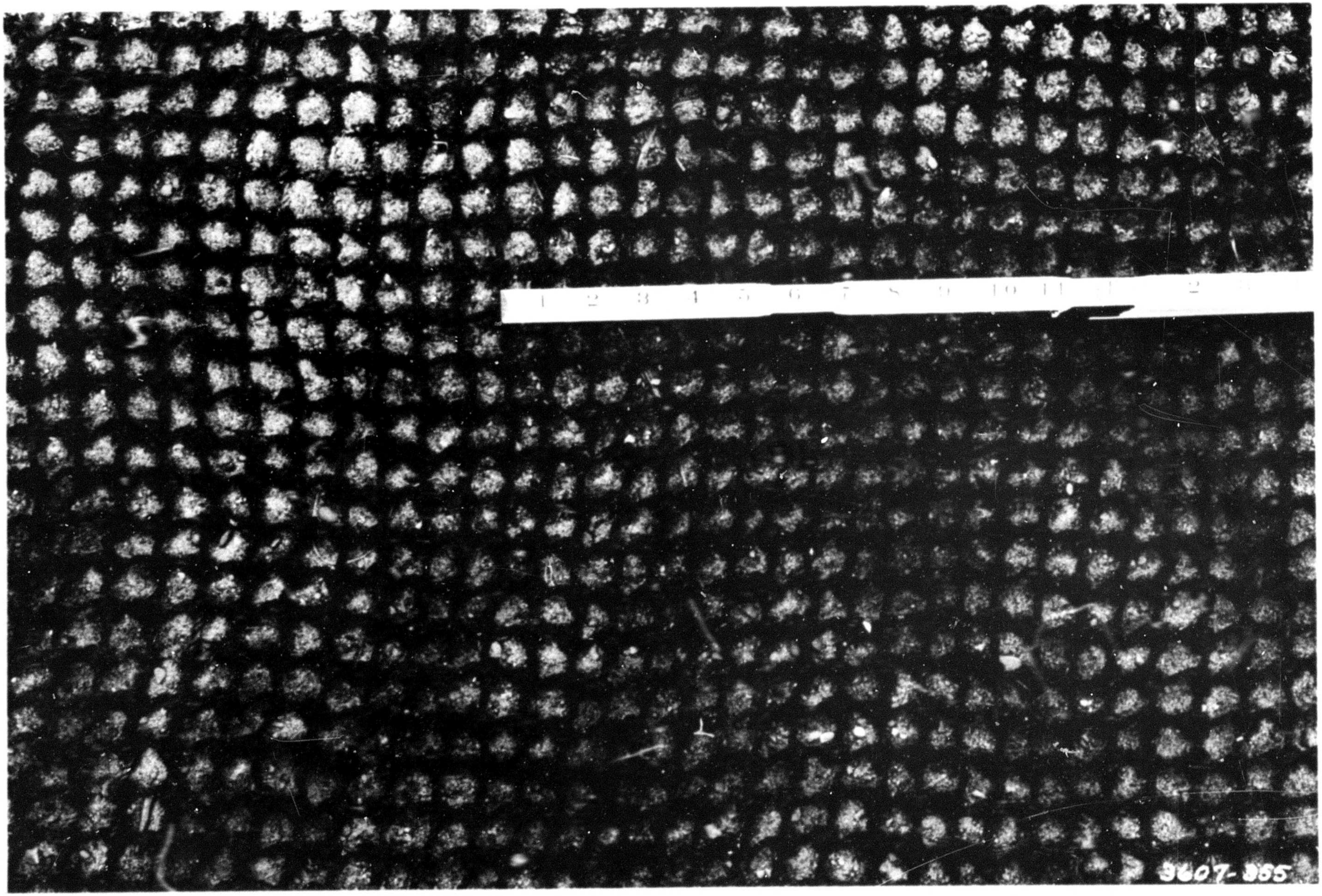
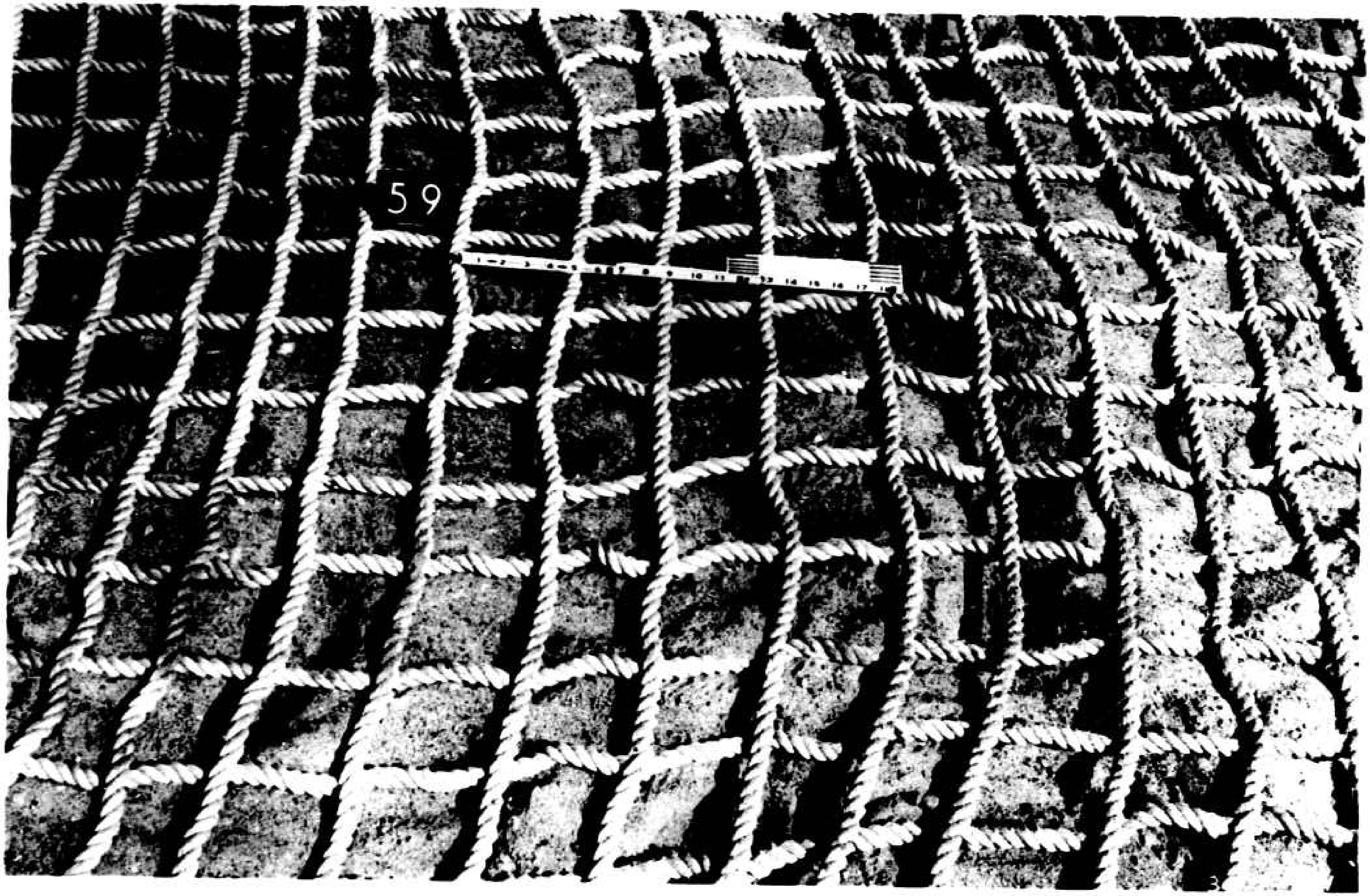
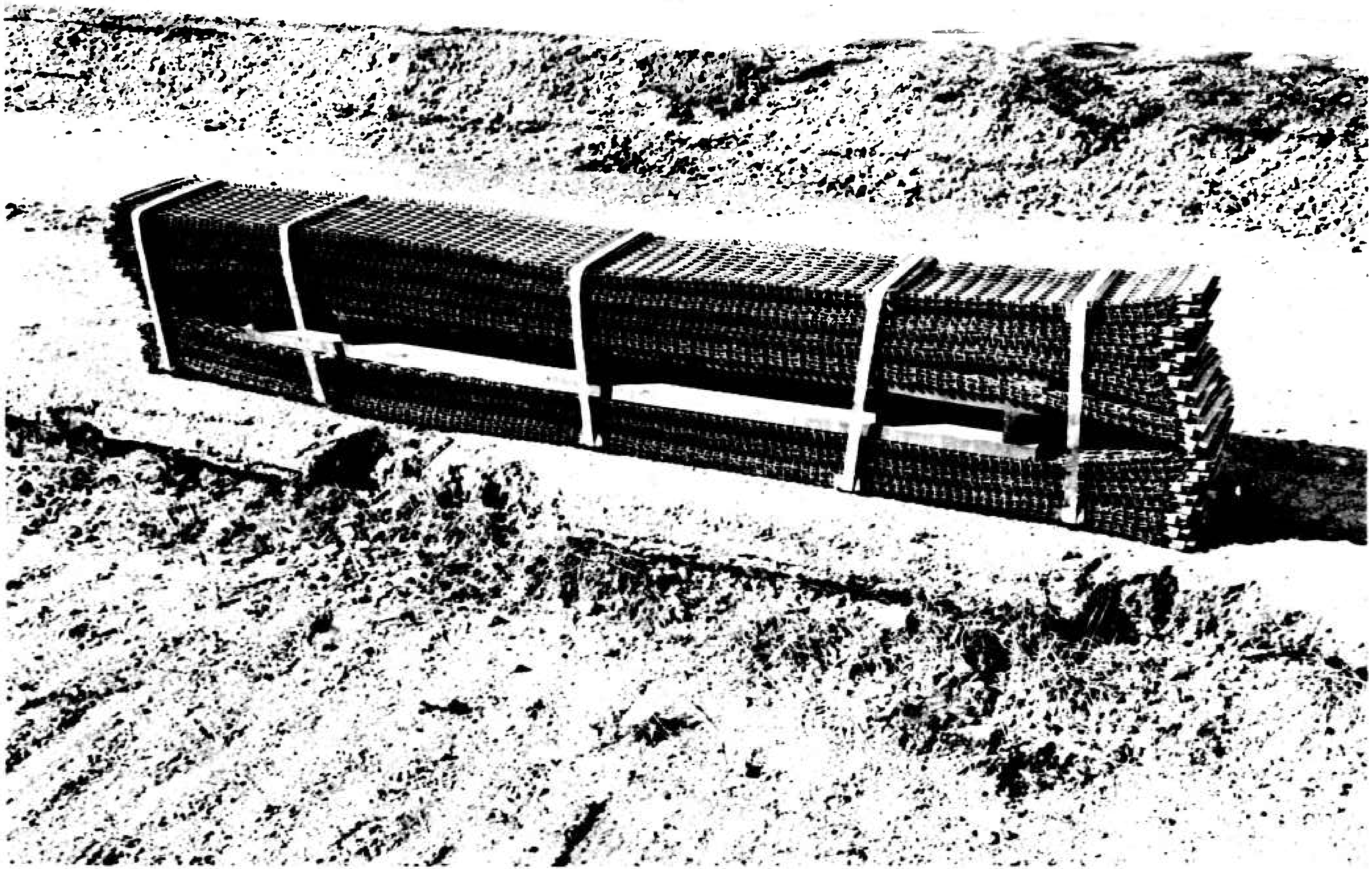


Photograph 1. Test item 1, nylon netting



Photograph 2. Test item 2, cargo netting



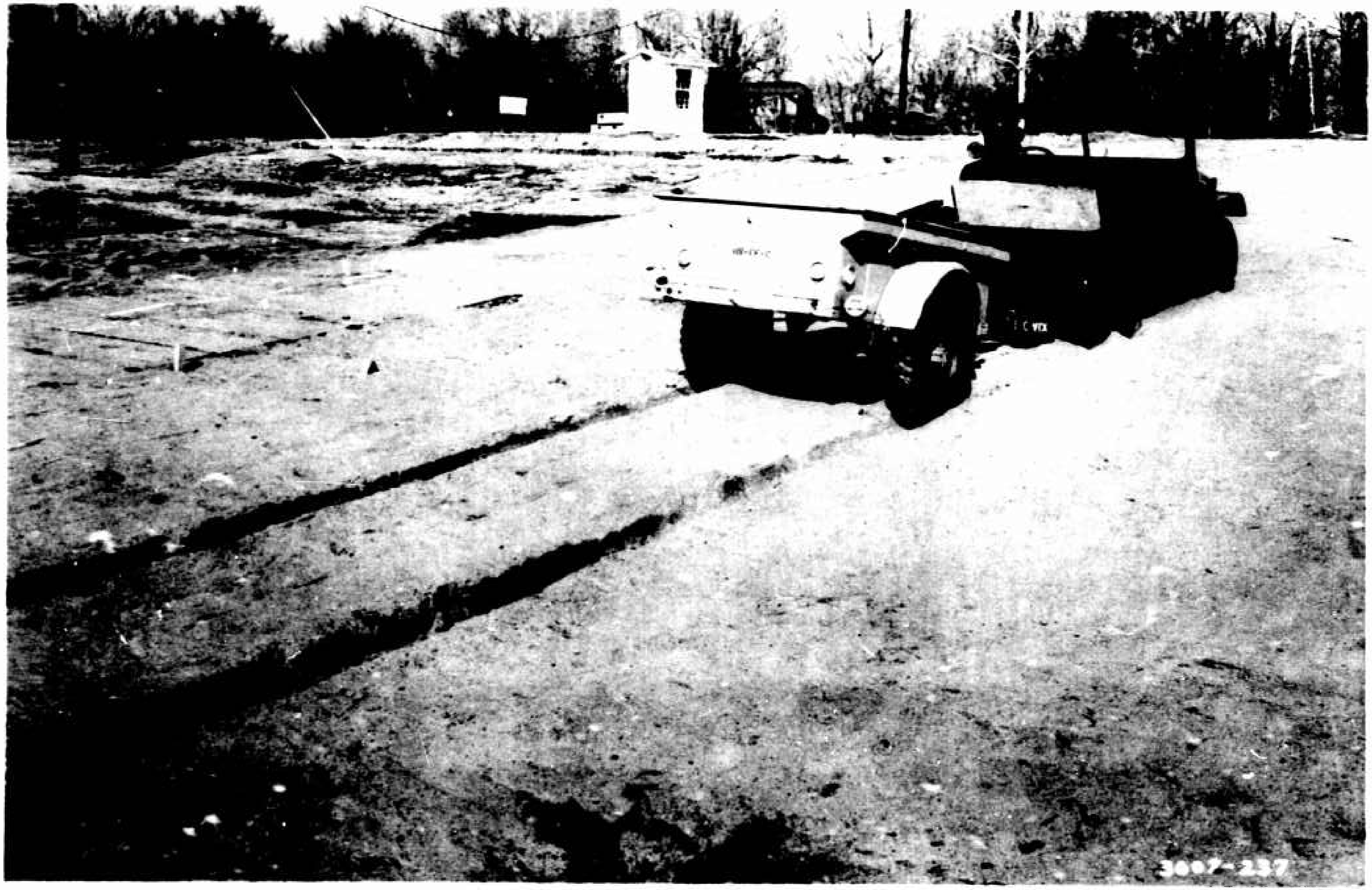
Photograph 3. Woven wire mat

Photograph 4. Test vehicles and trailers

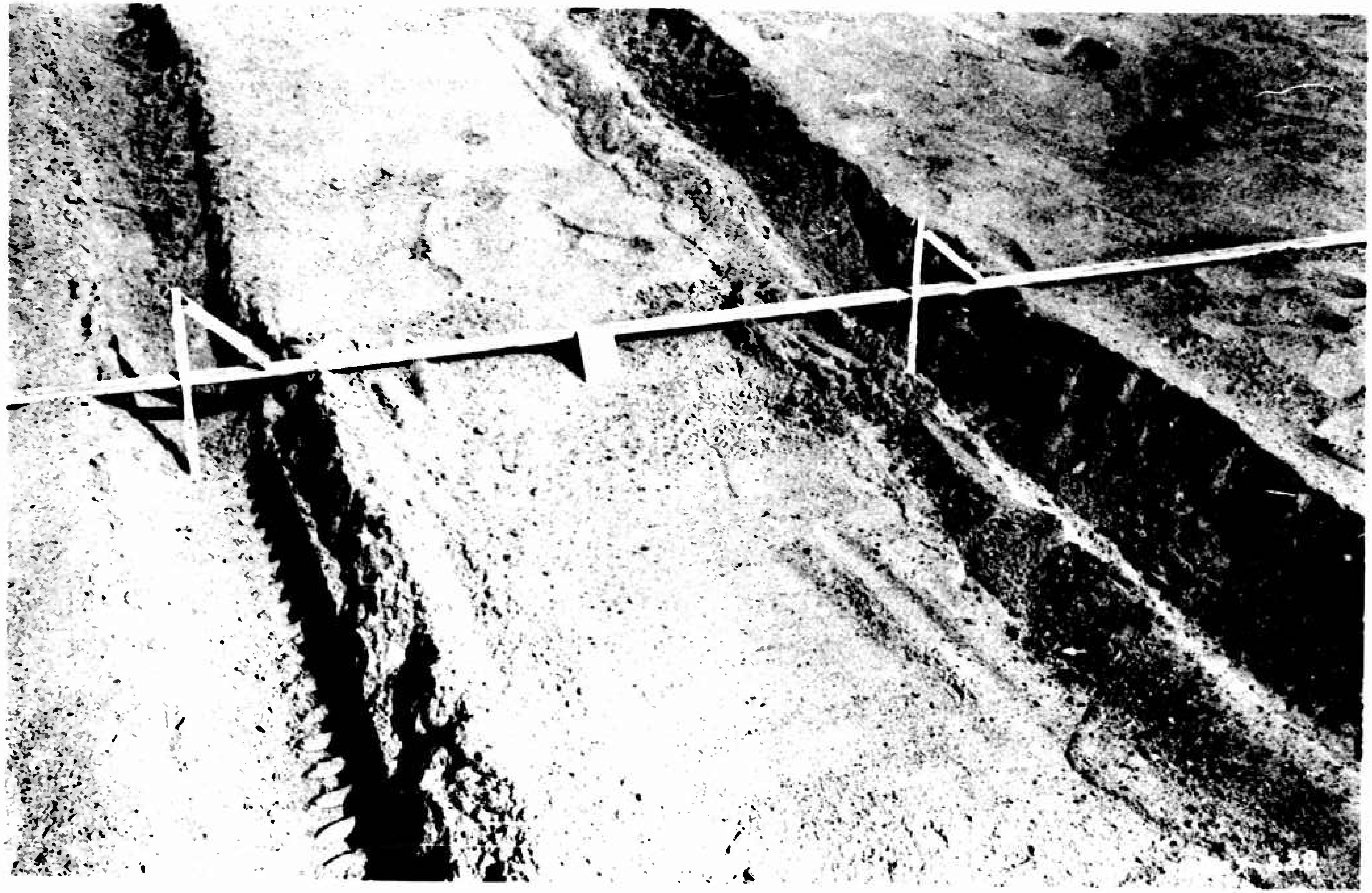
Photograph 5. Vehicles and trailers loaded with lead weights and steel ballast

Photograph 6. Spreading and sloping sand

Photograph 7. Sloped sand test section prior to traffic tests



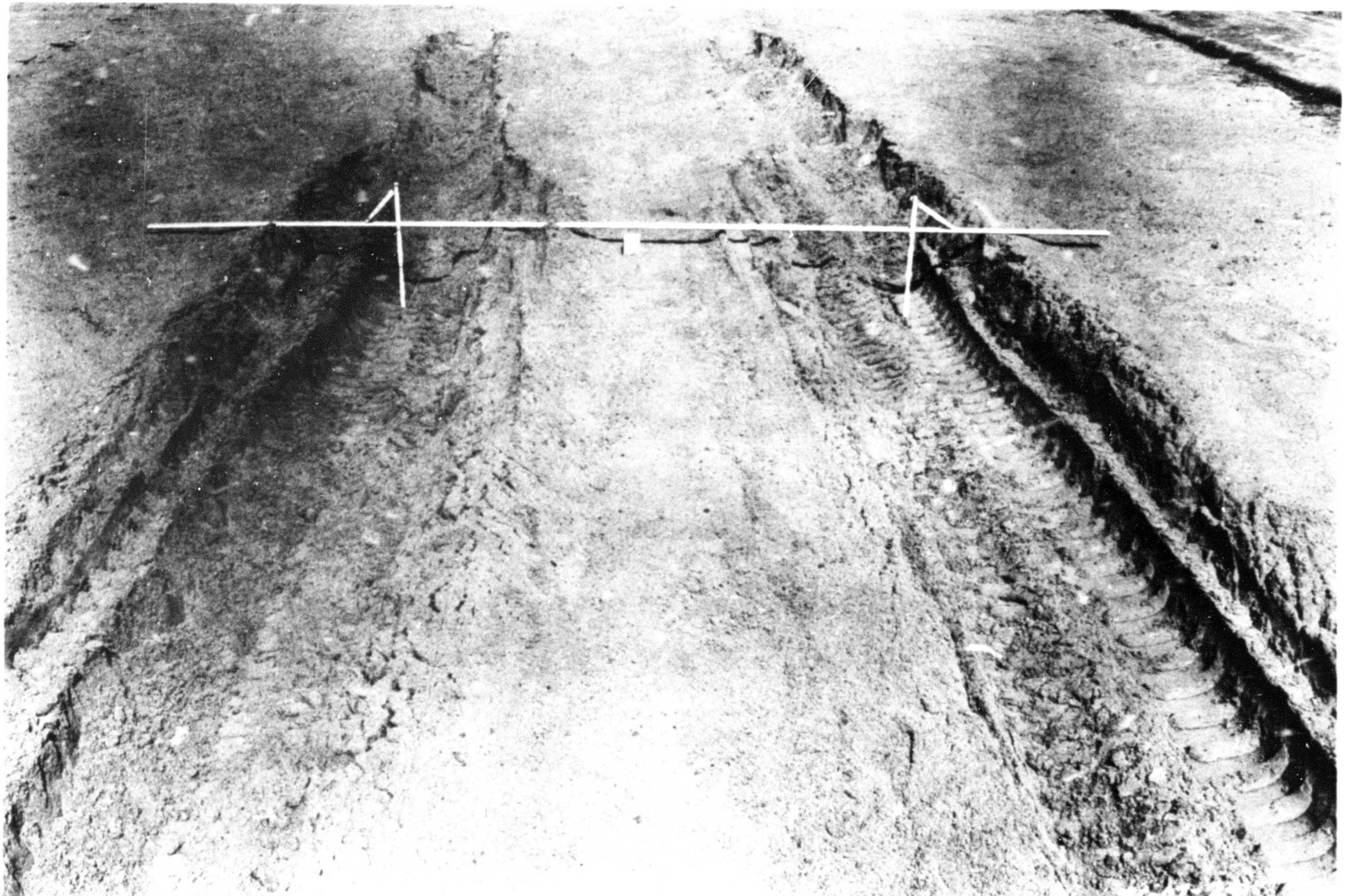
Photograph 8. M38A1 jeep with trailer immobilized on the sand test section



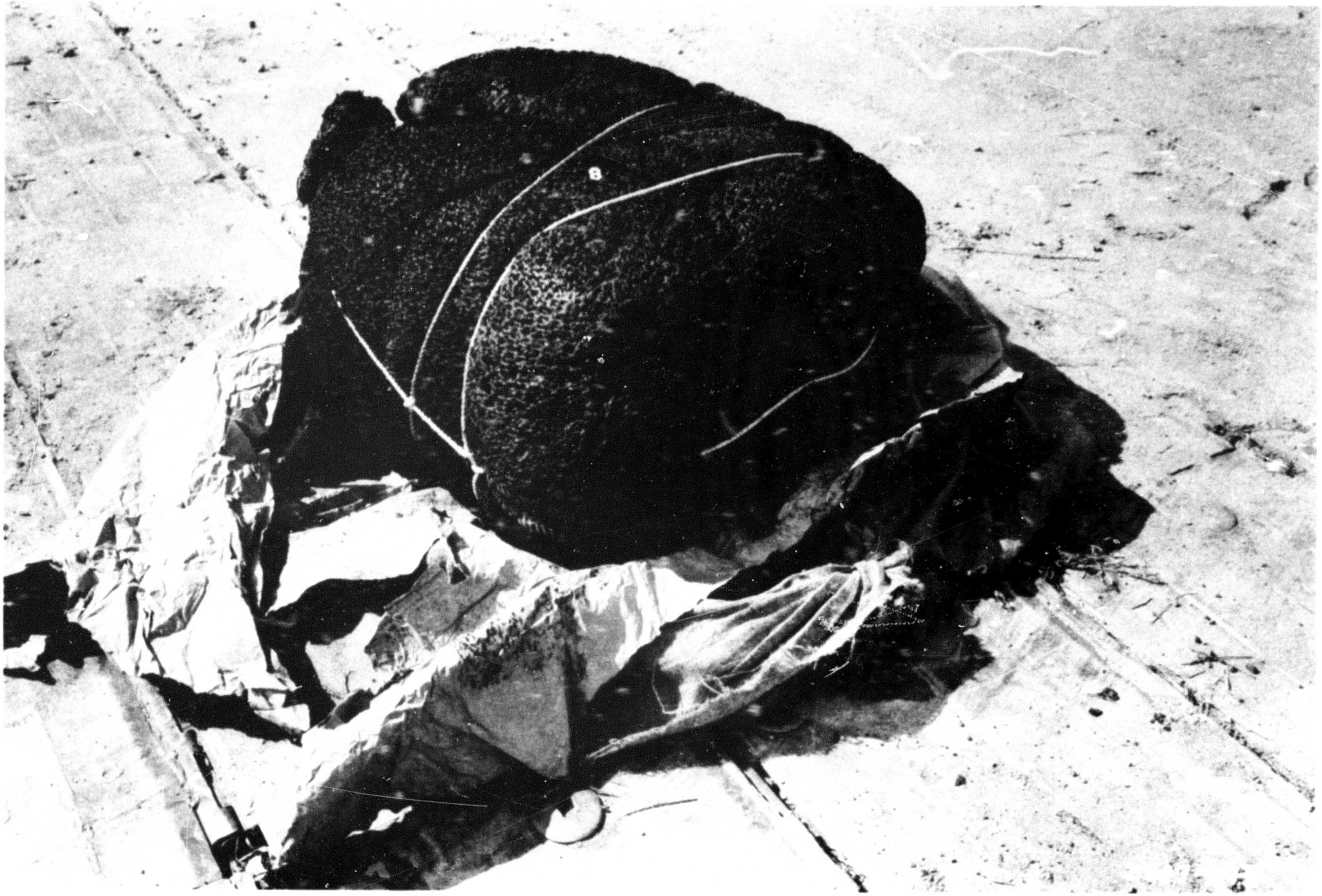
Photograph 9. Ruts in sand subgrade caused by immobilization of M38A1 jeep with M100, 1/4-ton trailer

Photograph 10. M37, 3/4-ton, 4x4 truck with M101, 3/4-ton trailer immobilized on sand test section

Photograph 11. M54, 5-ton, 6x6 truck with 2-W-M101, 1-ton trailer immobilized on sand test section



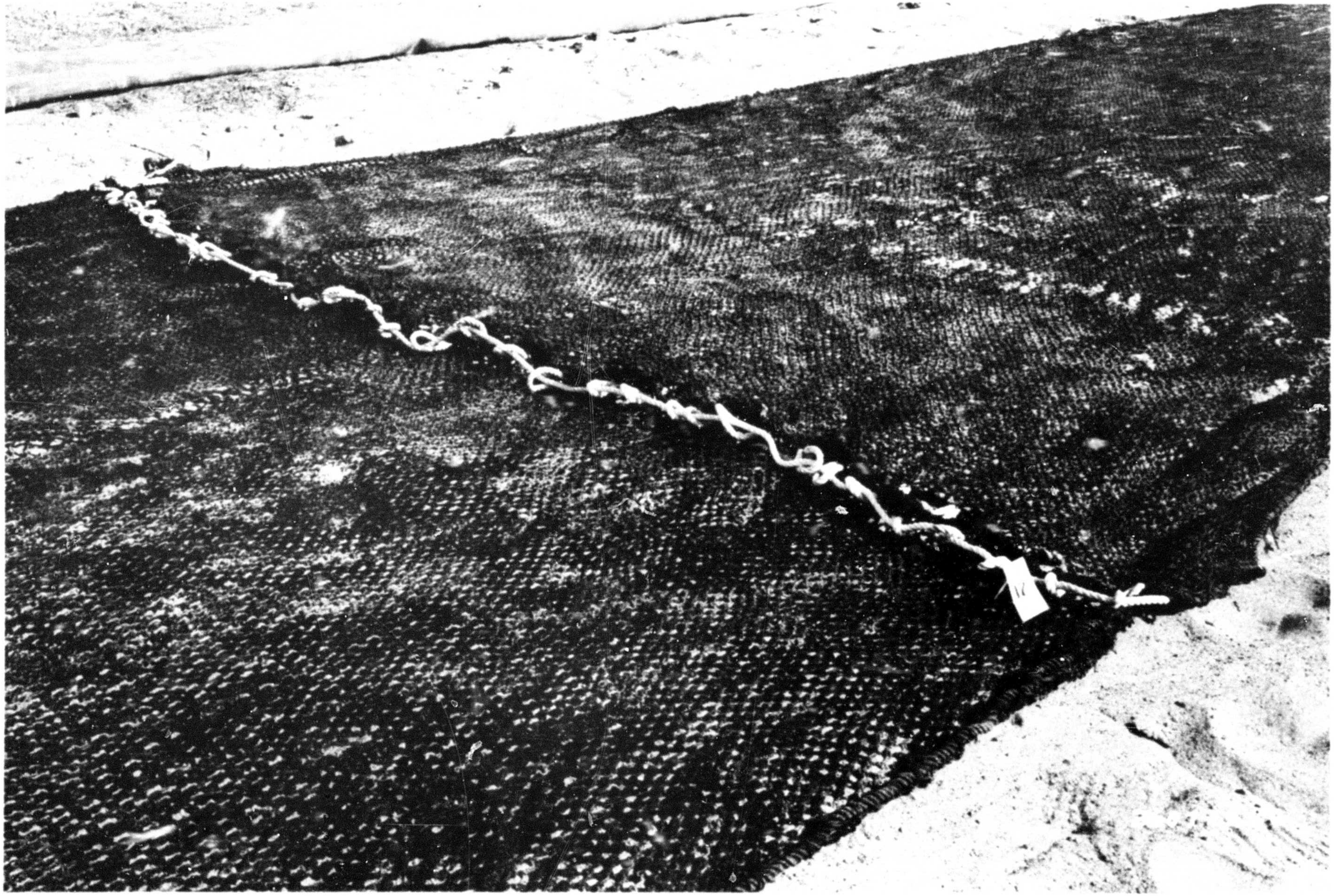
Photograph 12. Ruts in sand subgrade caused by immobilization of M54, 5-ton, 6x6 truck with 2-W-M101, 1-ton trailer



Photograph 13. Item 1 as received from manufacturer

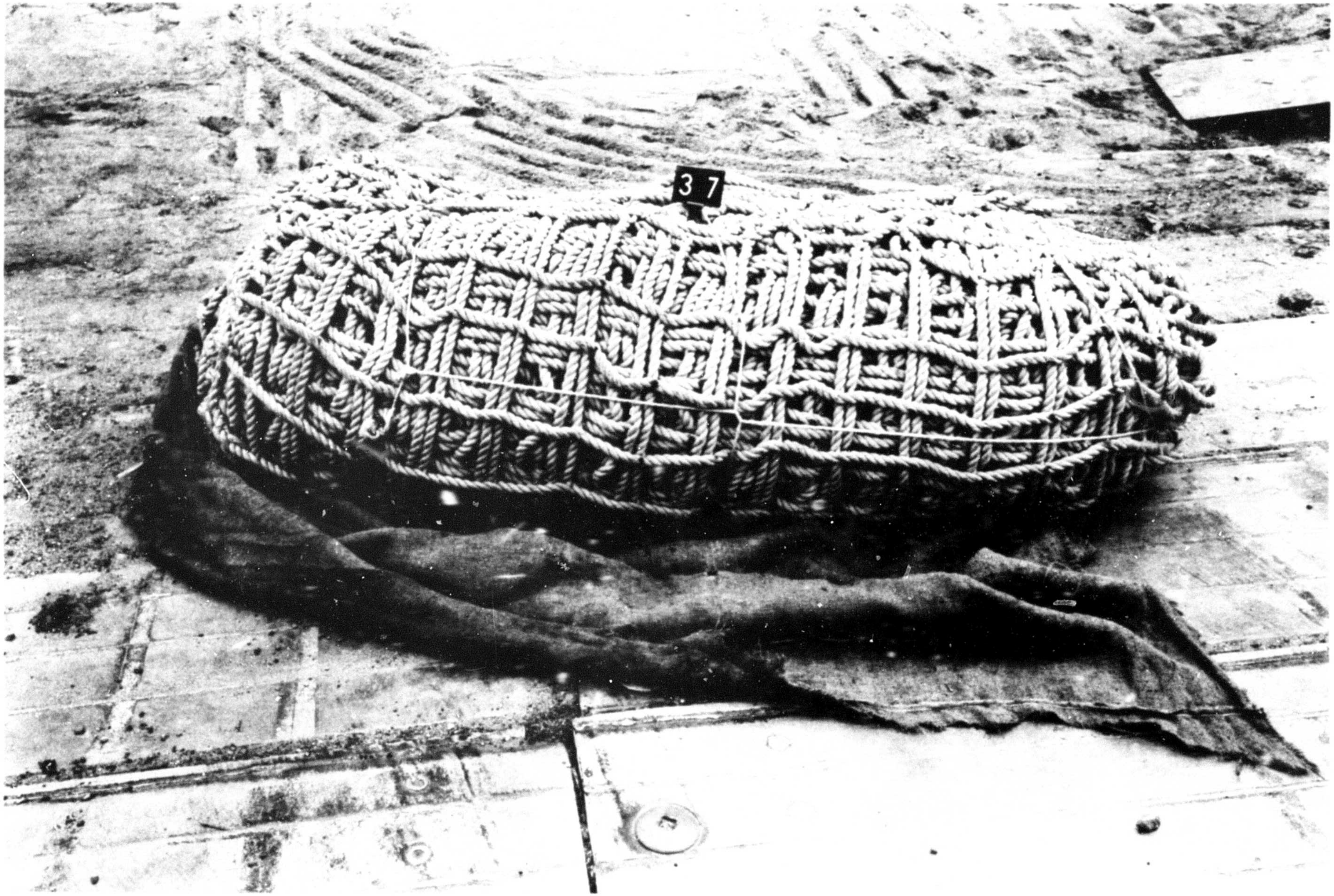
Photograph 14. Item 1 unfolded along center line of test section

Photograph 15. First section of item 1 unfolded and stretched upon sand test section

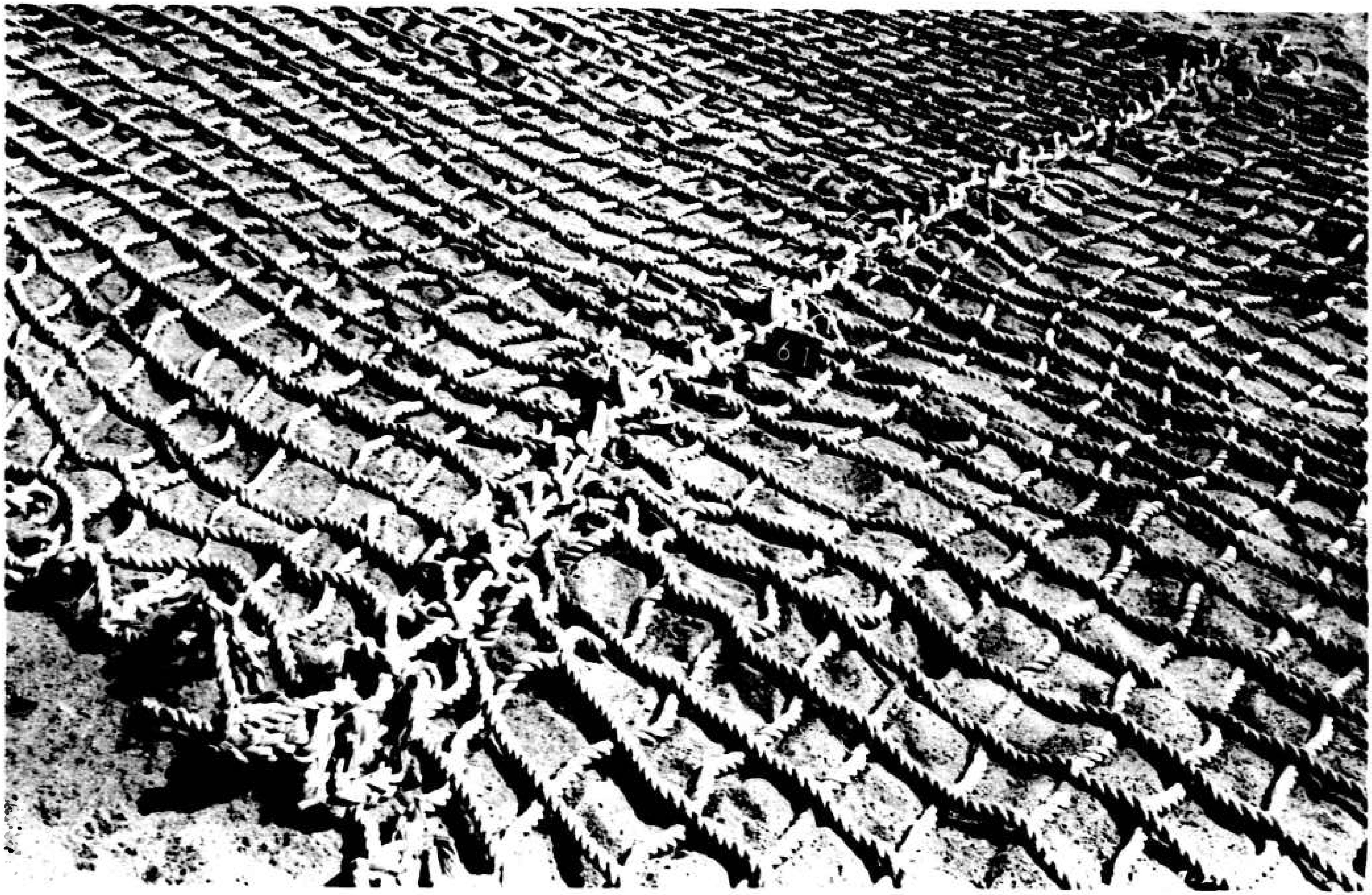


Photograph 16. Sections of item 1 lashed together at the ends to form a continuous net surfacing

Photograph 17. Item 1 prior to vehicle traffic tests



Photograph 18. Item 2 as received from manufacturer

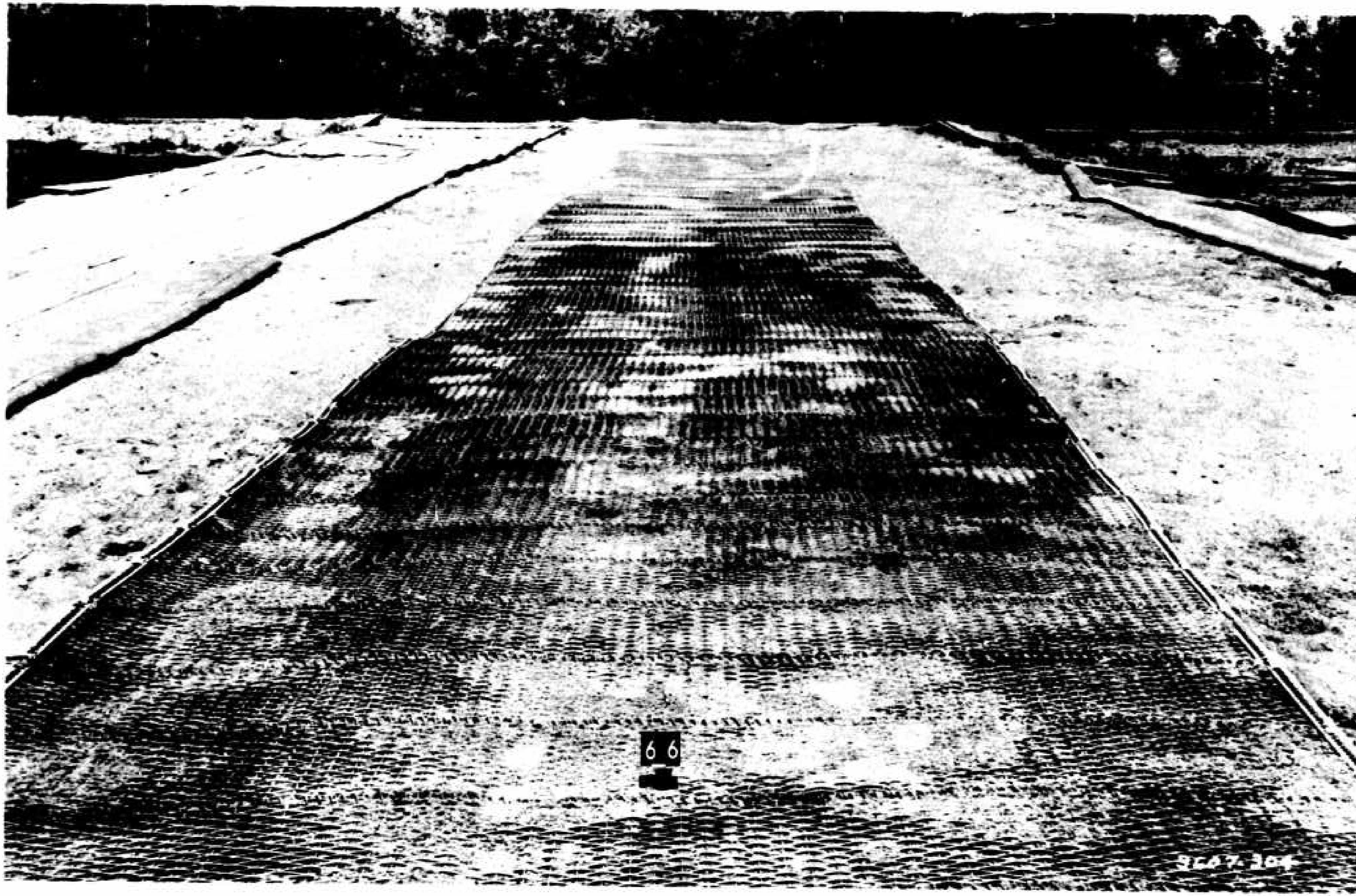


Photograph 19. Sections of item 2 lashed together at the ends to form a continuous surfacing

Photograph 20. Item 2 prior to vehicle traffic tests

Photograph 21. Forklift positioning bundles of woven wire beach mat at lower end of sand test section

Photograph 22. Placement of woven wire beach mat on sand test section



Photograph 24. Woven wire beach mat prior to vehicle traffic tests

Photograph 23. M51, 5-ton, 6x6 truck with beach mat spreading frame

Photograph 25. Item 1 after first pass of M38A1 jeep with trailer

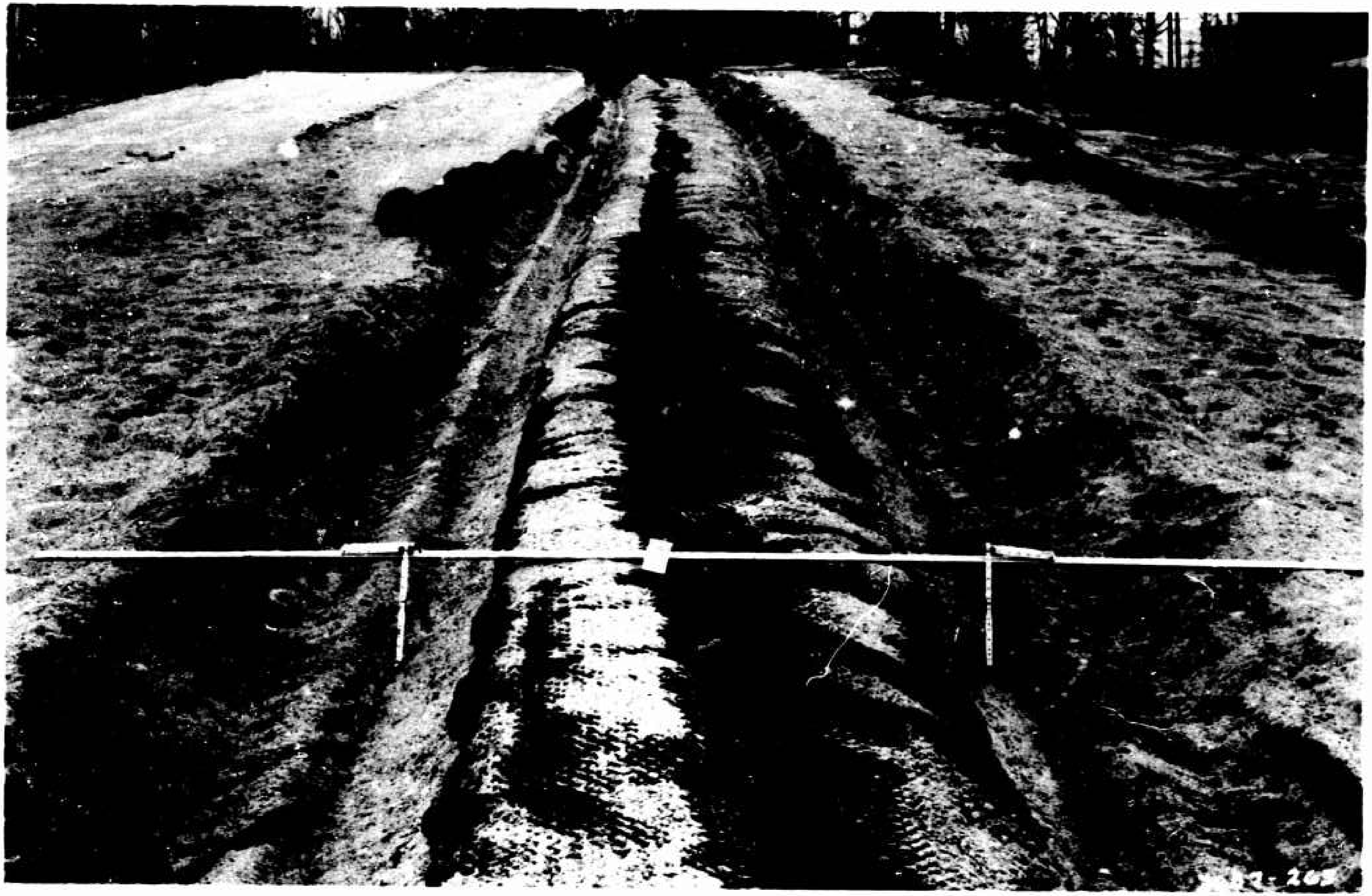
Photograph 26. Item 1 after initial pass of M37, 3/4-ton, 4x4 truck with trailer

Photograph 27. M54, 5-ton, 6x6 truck with 2-W-M101, 1-ton trailer immobilized during first pass on item 1

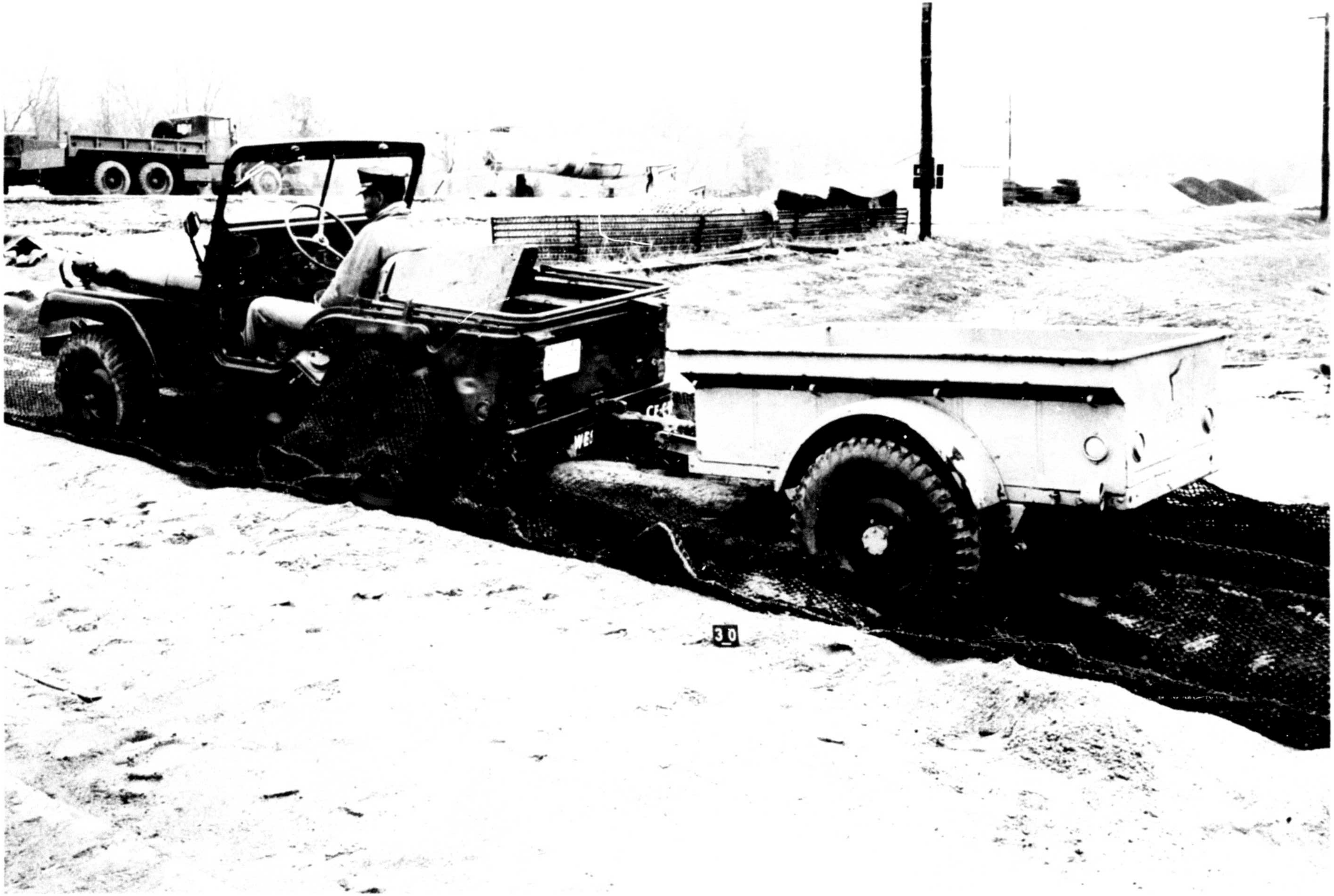
Photograph 28. Item 1 after immobilization of M54, 5-ton, 6x6 truck with 2-W-M101, 1-ton trailer

Photograph 29. Item 1 after 10 passes each of M38A1 jeep and M37 truck with trailers

Photograph 30. Item 1 after mixed vehicle traffic of one LST and 408,600 lb had been transported across sand test section

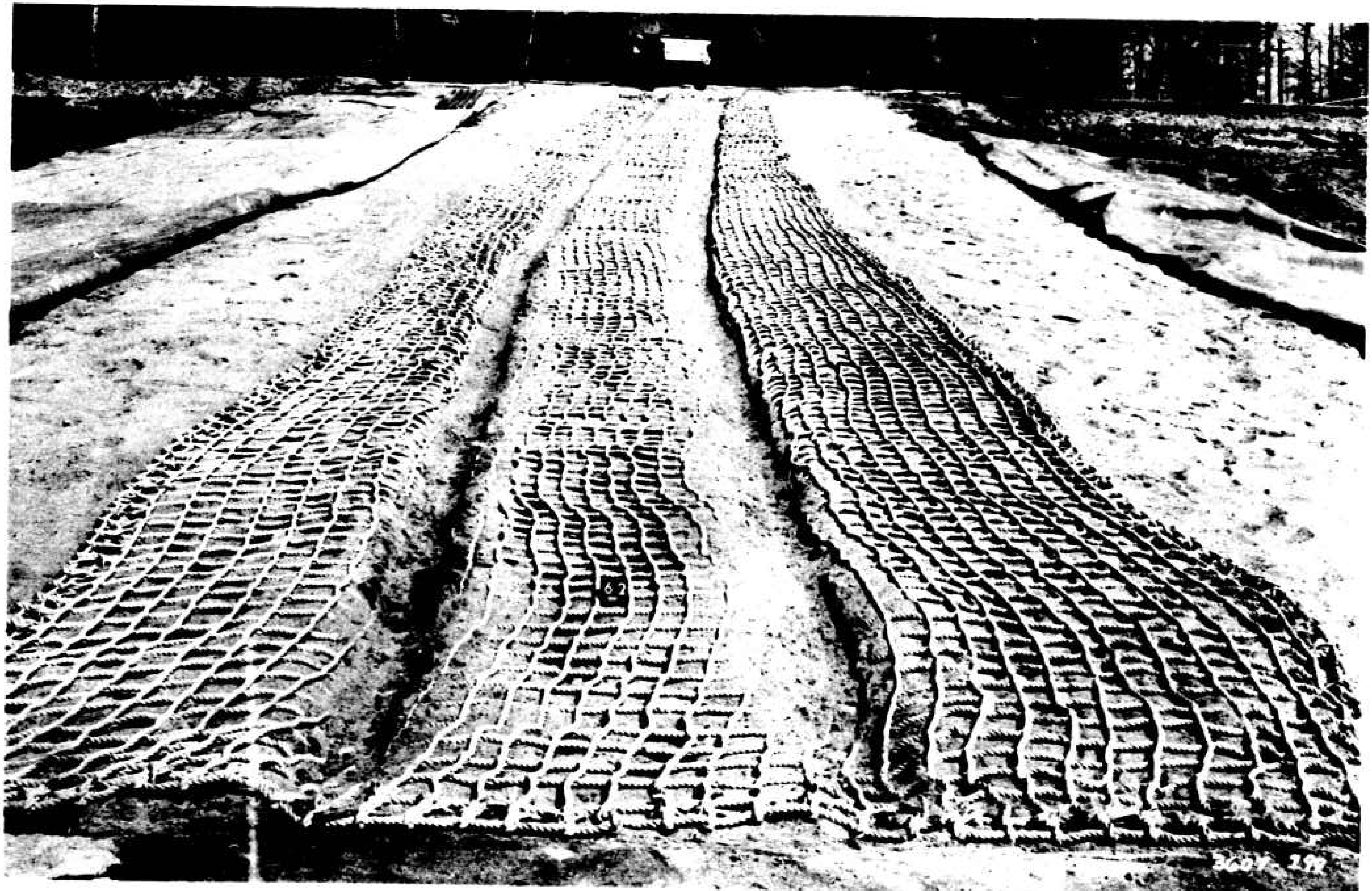


Photograph 31. Ruts 11 to 12 in. deep in sand subgrade caused by vehicle traffic of one LST across item 1

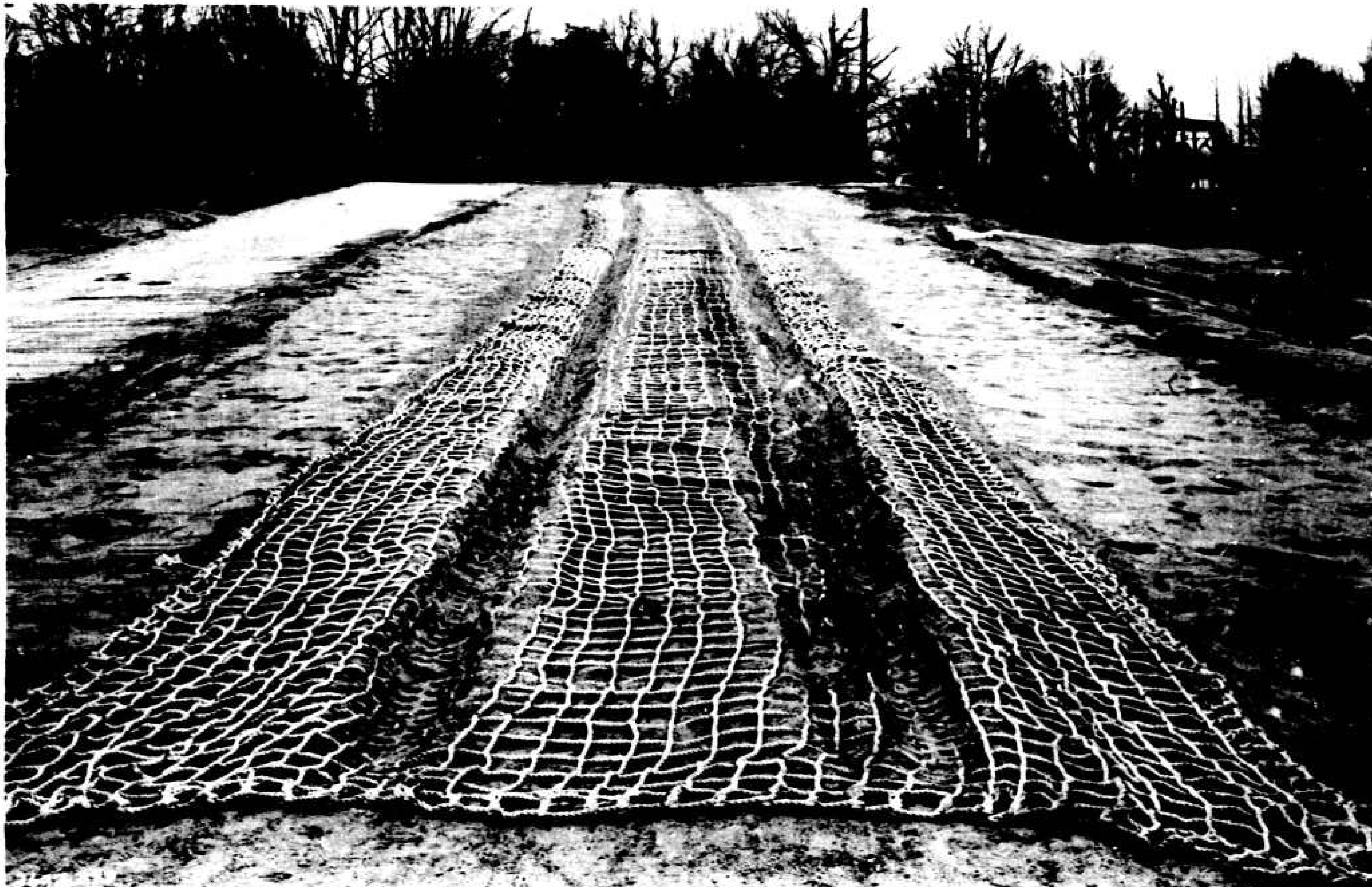


Photograph 32. M38A1 jeep immobilized on item 1. (The vehicle was immobilized on the third pass while simulating the vehicle traffic of the second LST)

Photograph 33. Item 1 after vehicle traffic of two LST's (less 19 passes of jeep and trailer) and a total load of 742,035 lb had been transported across the test section



Photograph 34. Item 2 after initial pass of M38A1 jeep with trailer

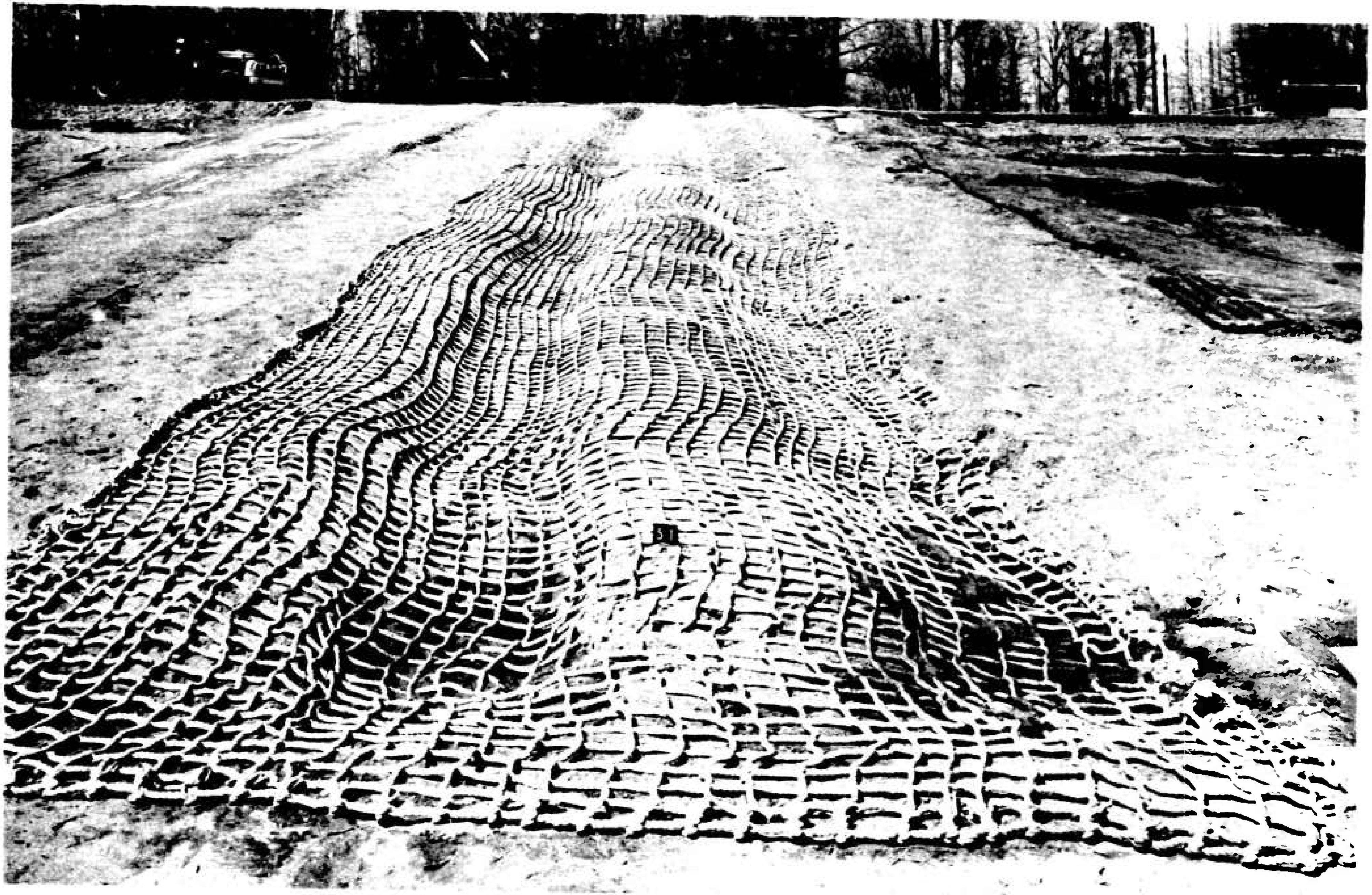


Photograph 35. Item 2 after initial pass of M37 truck with trailer

Photograph 36. Item 2 after initial pass of M54 truck with trailer

Photograph 37. Item 2 after mixed vehicle traffic of one LST and 408,600 lb had been transported across sand test section

Photograph 38. Ruts 8 to 9 in. deep in sand subgrade after vehicle traffic of one LST across item 2



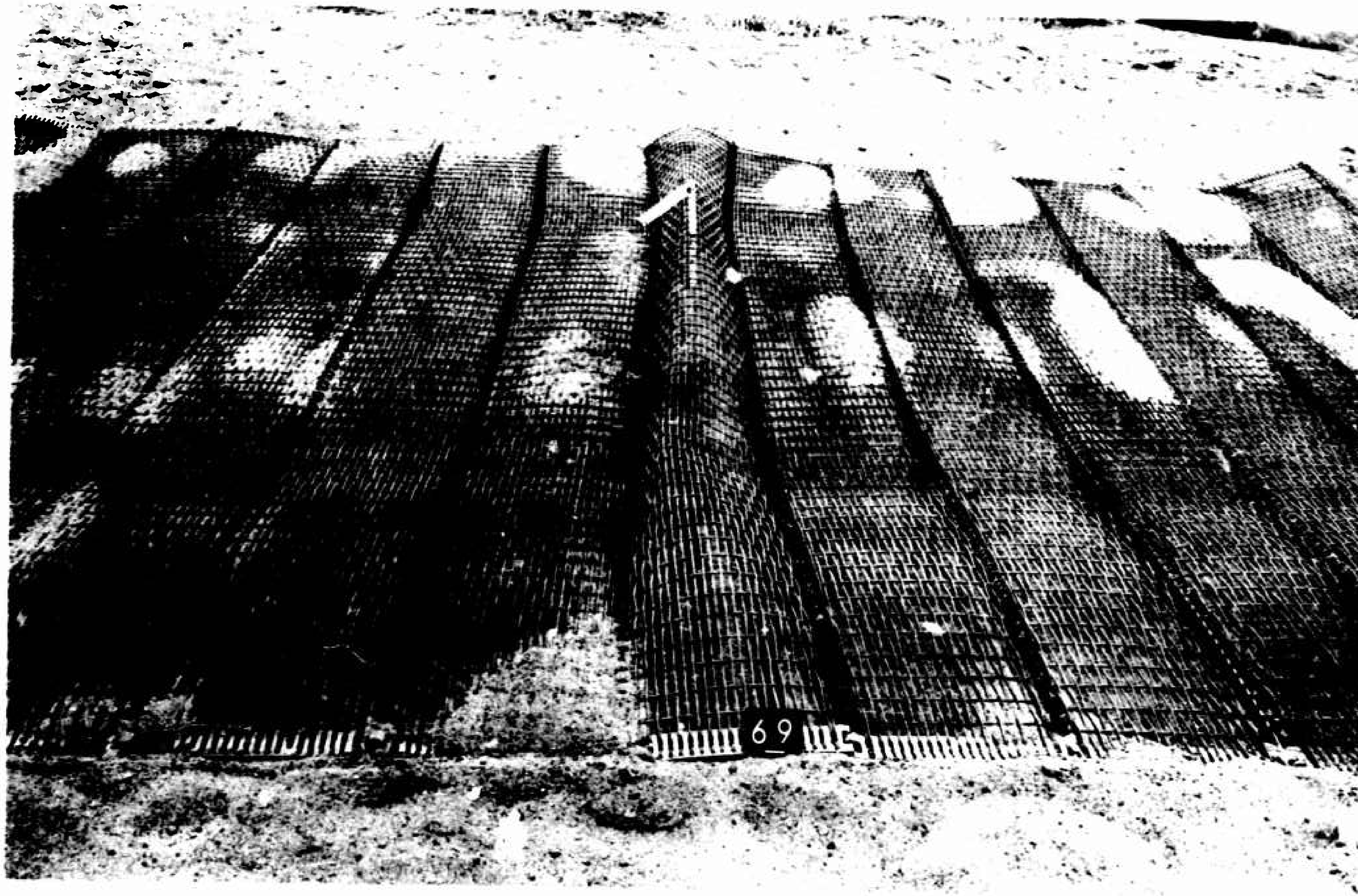
Photograph 39. Item 2 straightened and positioned on sand test section prior to vehicle traffic of second LST

Photograph 40. Item 2 after the initial passes of the three vehicles simulating traffic of the second LST

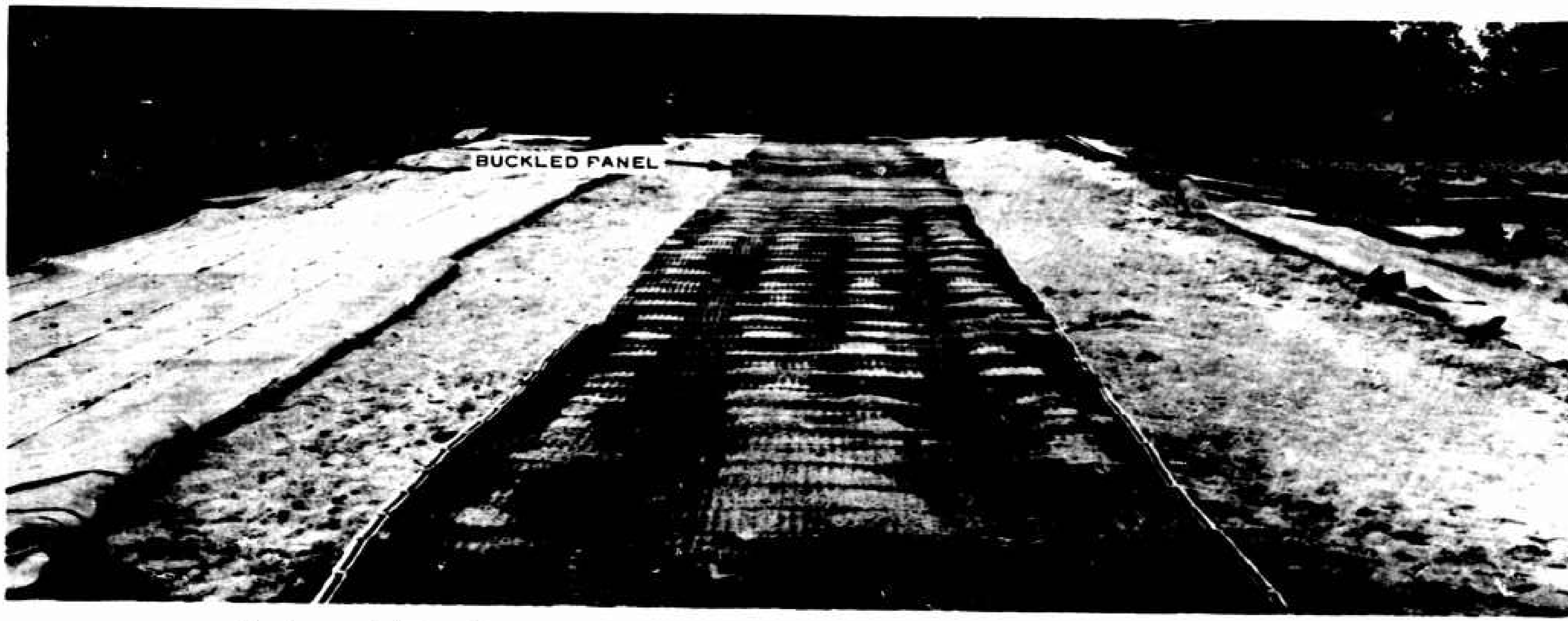
Photograph 41. Item 2 after vehicle traffic of the second LST and 813,950 lb had been transported across sand test section

Photograph 42. Ruts 9 to 10 in. deep in the sand subgrade after vehicle traffic of second LST across item 2

Photograph 43. Woven wire mat after initial pass of M38A1 jeep with trailer

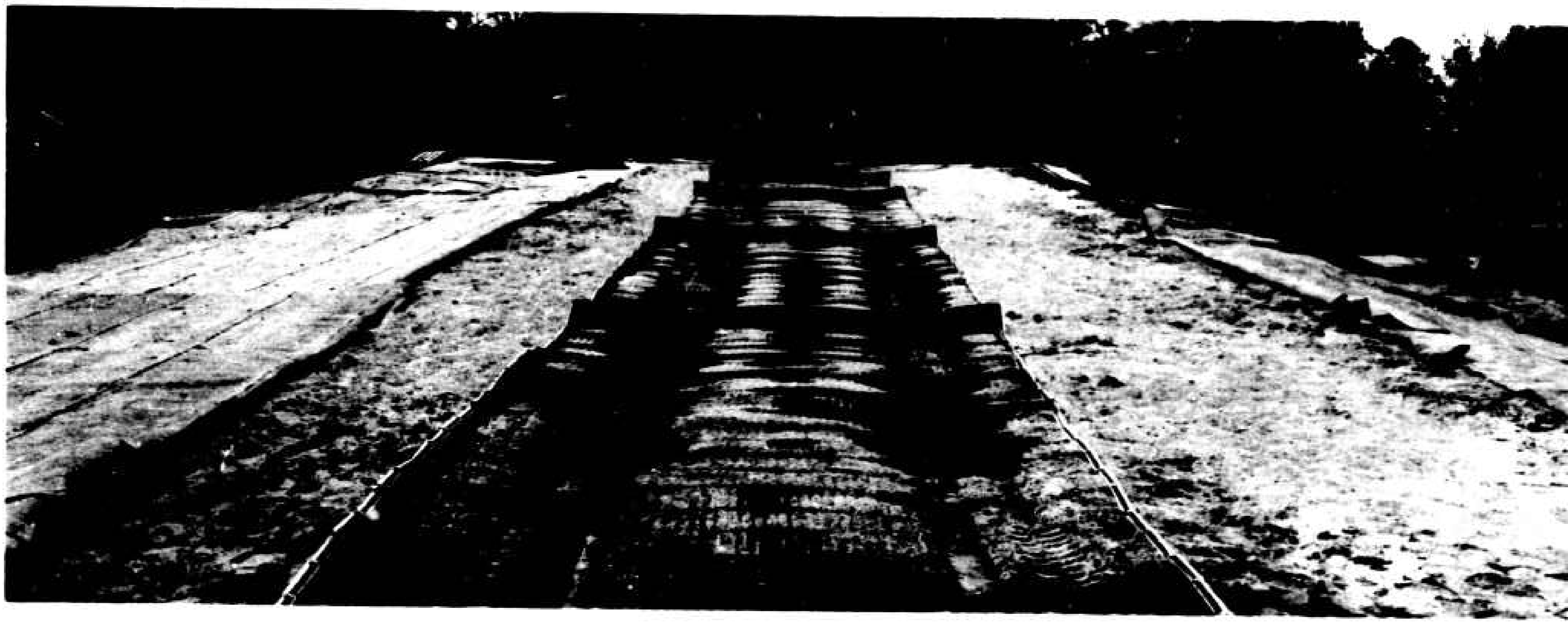


Photograph 44. Buckle in panel of woven wire beach mat caused by initial pass of M37 truck with trailer



Photograph 45. Woven wire mat after initial pass of M37 truck with trailer.
Note buckled panel near upper end of test section

Photograph 46. Buckled and deformed panels of woven wire mat caused by initial pass of M54 truck



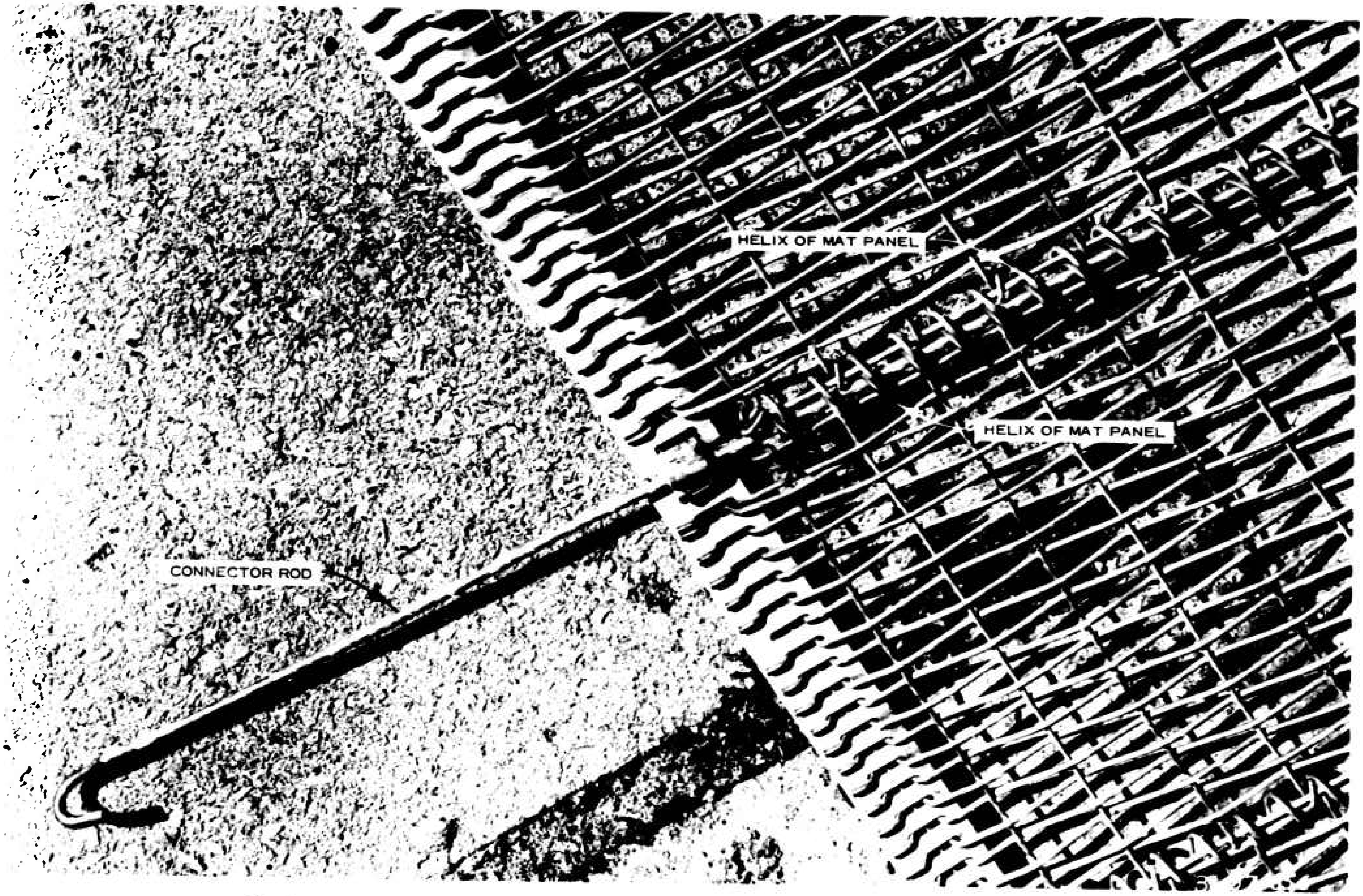
Photograph 47. Woven wire mat after initial pass of M54 truck with trailer

Photograph 49. Buckled, bent, and deformed woven wire mat after vehicle traffic of second LST

Photograph 48. Woven wire mat after vehicle traffic of one LST

Photograph 49. Buckled, bent, and deformed woven wire mat after

Photograph 50. Woven wire mat after traffic of second LST



Photograph 51. Connector rod used to join end par.ls of mat sectons

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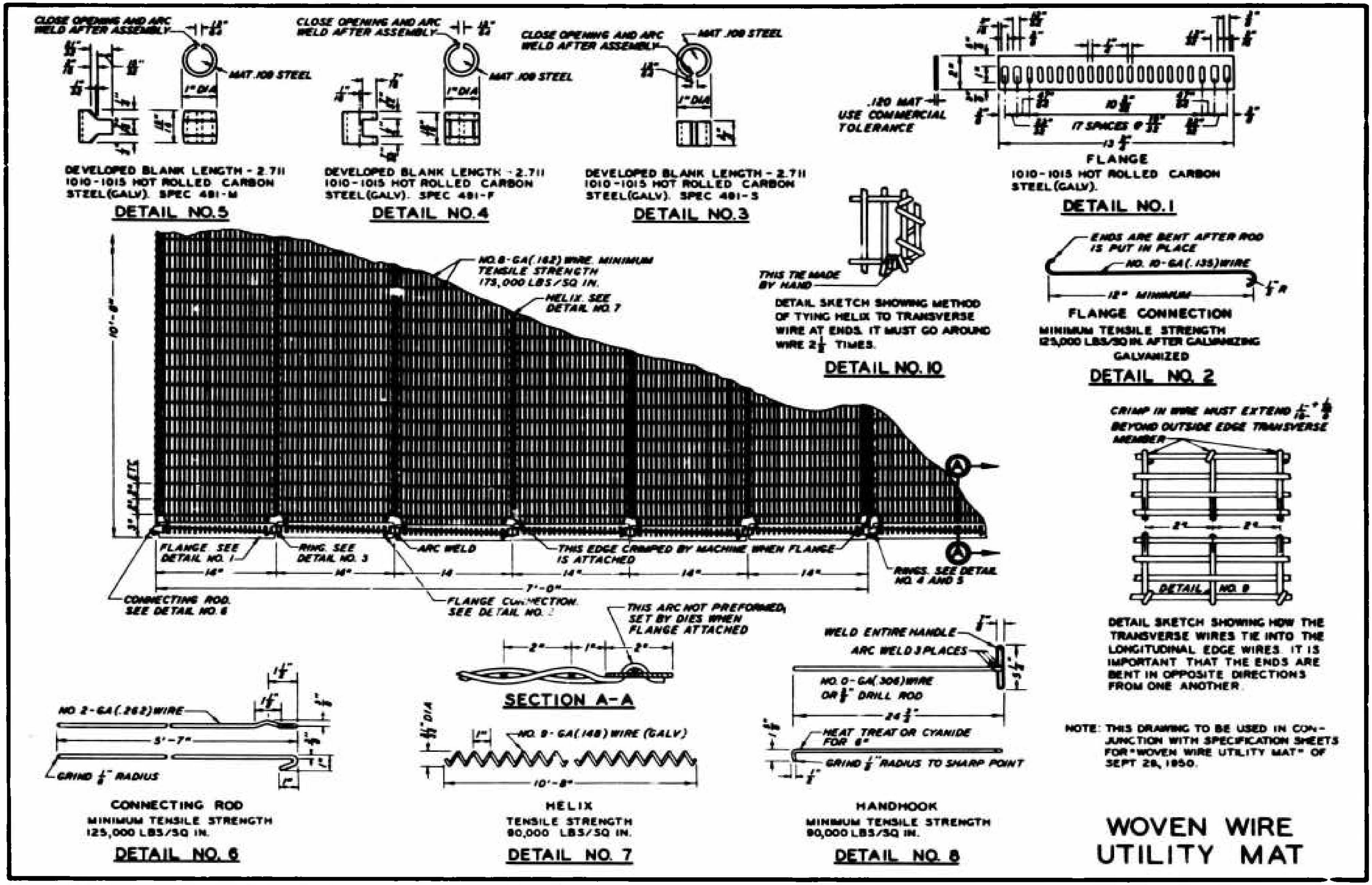
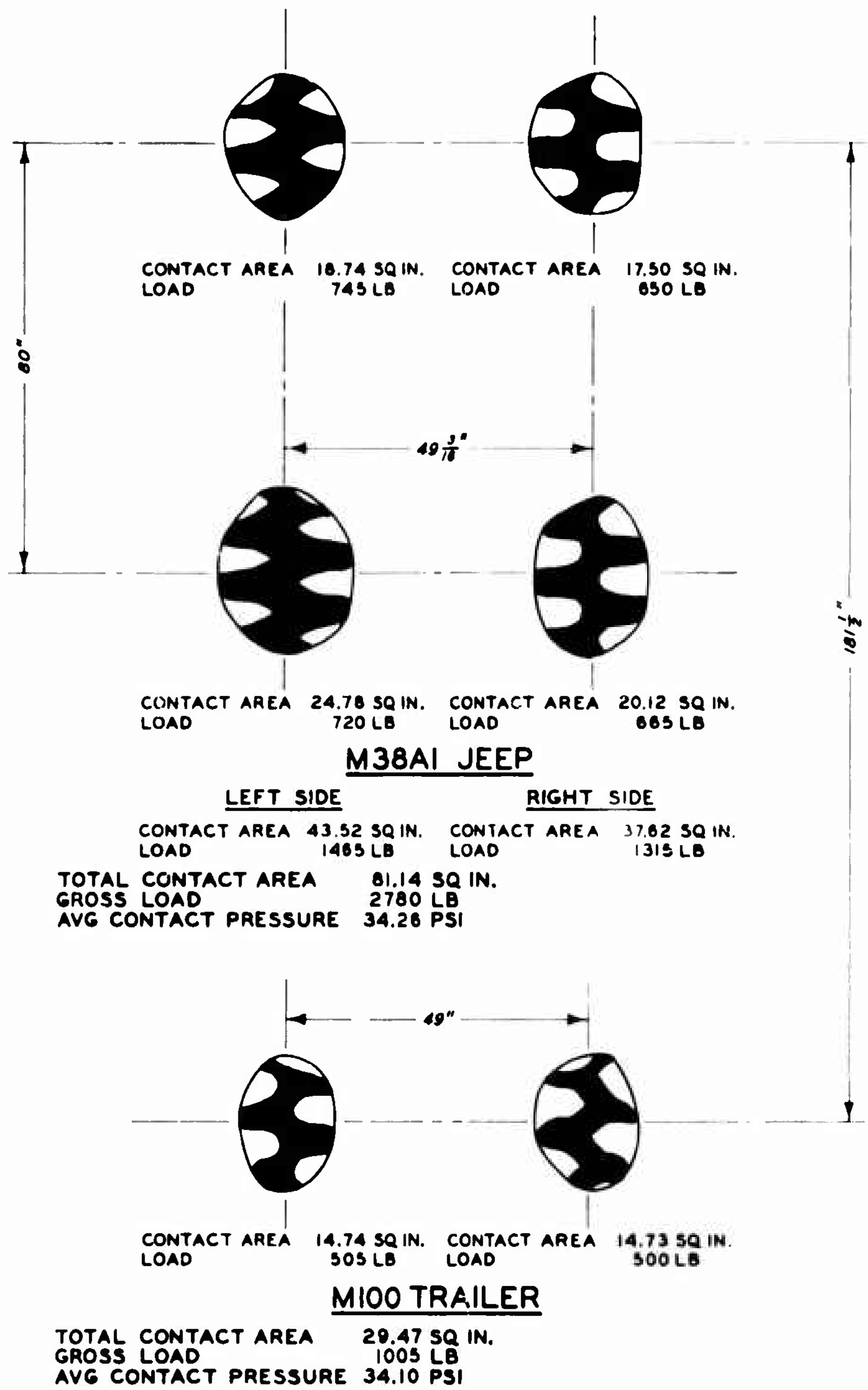

CLOSE OPENING AND ARC WELD AFTER ASSEMBLY
MAT. JOB STEEL
1" DIA
DEVELOPED BLANK LENGTH - 2.711
1010-1015 HOT ROLLED CARBON STEEL(GALV). SPEC 481-M
DETAIL NO.5
DEVELOPED BLANK LENGTH - 2.711
1010-1015 HOT ROLLED CARBON STEEL(GALV). SPEC 481-F
DETAIL NO.4
DEVELOPED BLANK LENGTH - 2.711
1010-1015 HOT ROLLED CARBON STEEL(GALV). SPEC 481-S
DETAIL NO.3
.120 MAT
USE COMMERCIAL TOLERANCE
17 SPACES
FLANGE
1010-1015 HOT ROLLED CARBON STEEL(GALV).
DETAIL NO.1
NO. 8-GA(.162) WIRE. MINIMUM TENSILE STRENGTH 175,000 LBS/SQ IN.
HELIX. SEE DETAIL NO. 7
10'-8"
THIS TIE MADE BY HAND
DETAIL SKETCH SHOWING METHOD OF TYING HELIX TO TRANSVERSE WIRE AT ENDS. IT MUST GO AROUND WIRE 2½ TIMES.
DETAIL NO. 10
ENDS ARE BENT AFTER ROD IS PUT IN PLACE
NO. 10-GA(.135)WIRE
12" MINIMUM
FLANGE CONNECTION
MINIMUM TENSILE STRENGTH 125,000 LBS/SQ IN. AFTER GALVANIZING
GALVANIZED
DETAIL NO. 2
CRIMP IN WIRE MUST EXTEND BEYOND OUTSIDE EDGE TRANSVERSE MEMBER
DETAIL NO. 9
DETAIL SKETCH SHOWING HOW THE TRANSVERSE WIRES TIE INTO THE LONGITUDINAL EDGE WIRES. IT IS IMPORTANT THAT THE ENDS ARE BENT IN OPPOSITE DIRECTIONS FROM ONE ANOTHER.
FLANGE SEE DETAIL NO. 1
RING SEE DETAIL NO. 3
ARC WELD
THIS EDGE CRIMPED BY MACHINE WHEN FLANGE IS ATTACHED
RINGS SEE DETAIL NO. 4 AND 5
14"
7'-0"
CONNECTING ROD SEE DETAIL NO. 6
FLANGE CONNECTION SEE DETAIL NO. 2
THIS ARC NOT PREFORMED, SET BY DIES WHEN FLANGE ATTACHED
SECTION A-A
WELD ENTIRE HANDLE
ARC WELD 3 PLACES
NO. 0-GA(.306)WIRE OR ⅜" DRILL ROD
HEAT TREAT OR CYANIDE FOR 6"
GRIND ⅛" RADIUS TO SHARP POINT
NOTE: THIS DRAWING TO BE USED IN CONJUNCTION WITH SPECIFICATION SHEETS FOR "WOVEN WIRE UTILITY MAT" OF SEPT 28, 1950.
NO 2-GA(.262)WIRE
5'-7"
GRIND ⅛" RADIUS
CONNECTING ROD
MINIMUM TENSILE STRENGTH 125,000 LBS/SQ IN.
DETAIL NO. 6
NO. 9-GA(.148) WIRE (GALV)
10'-8"
HELIX
TENSILE STRENGTH 80,000 LBS/SQ IN.
DETAIL NO. 7
HANDHOOK
MINIMUM TENSILE STRENGTH 80,000 LBS/SQ IN.
DETAIL NO. 8
WOVEN WIRE UTILITY MAT

PLATE I



VEHICLE LOADING DATA

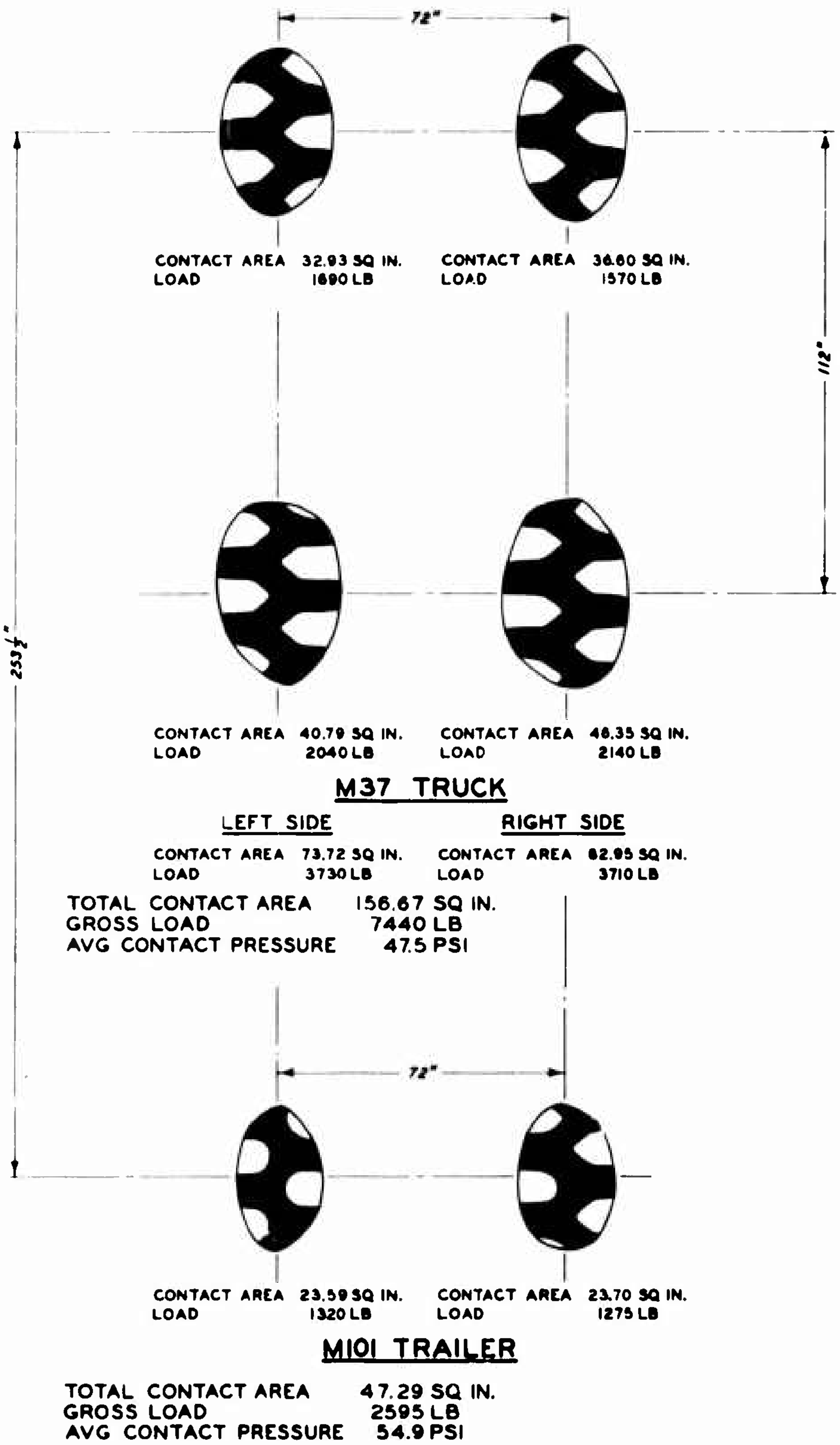
M38A1 JEEP AND

M100, $\frac{1}{4}$ - TON TRAILER

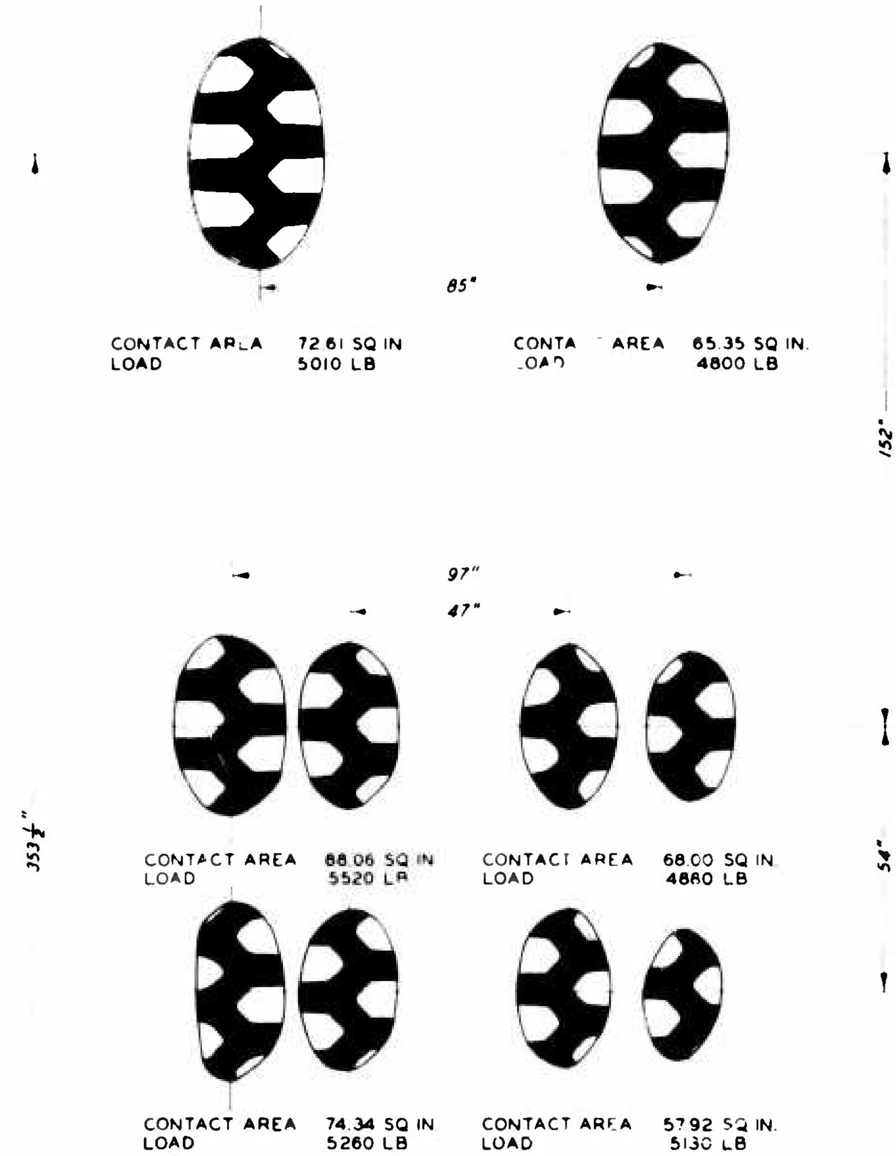
7.00-16, 6-PR TIRES

28 - PSI INFLATION PRESSURE

PLATE 2



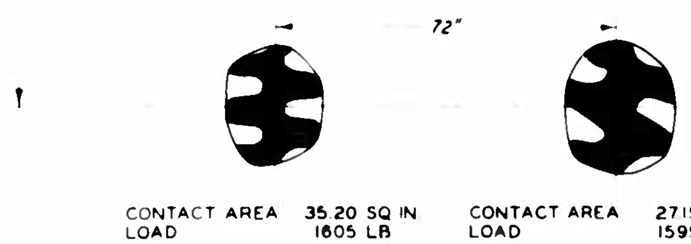
VEHICLE LOADING DATA
M37, ¾-TON, 4X4 TRUCK
AND M101, ¾-TON TRAILER
9.00-16, 8-PR TIRES
45-PSI INFLATION PRESSURE



M54 TRUCK

LEFT SIDE		RIGHT SIDE	
CONTACT AREA	235.01 SQ IN.	CONTACT AREA	191.27 SQ IN
LOAD	15,790 LB	LOAD	14,810 LB

TOTAL CONTACT AREA	426.28 SQ IN.
GROSS LOAD	30,600 LB
AVG CONTACT PRESSURE	71.78 PSI
TIRE SIZE	11.00-20, 12-PR
INFLATION PRESSURE	70 PSI

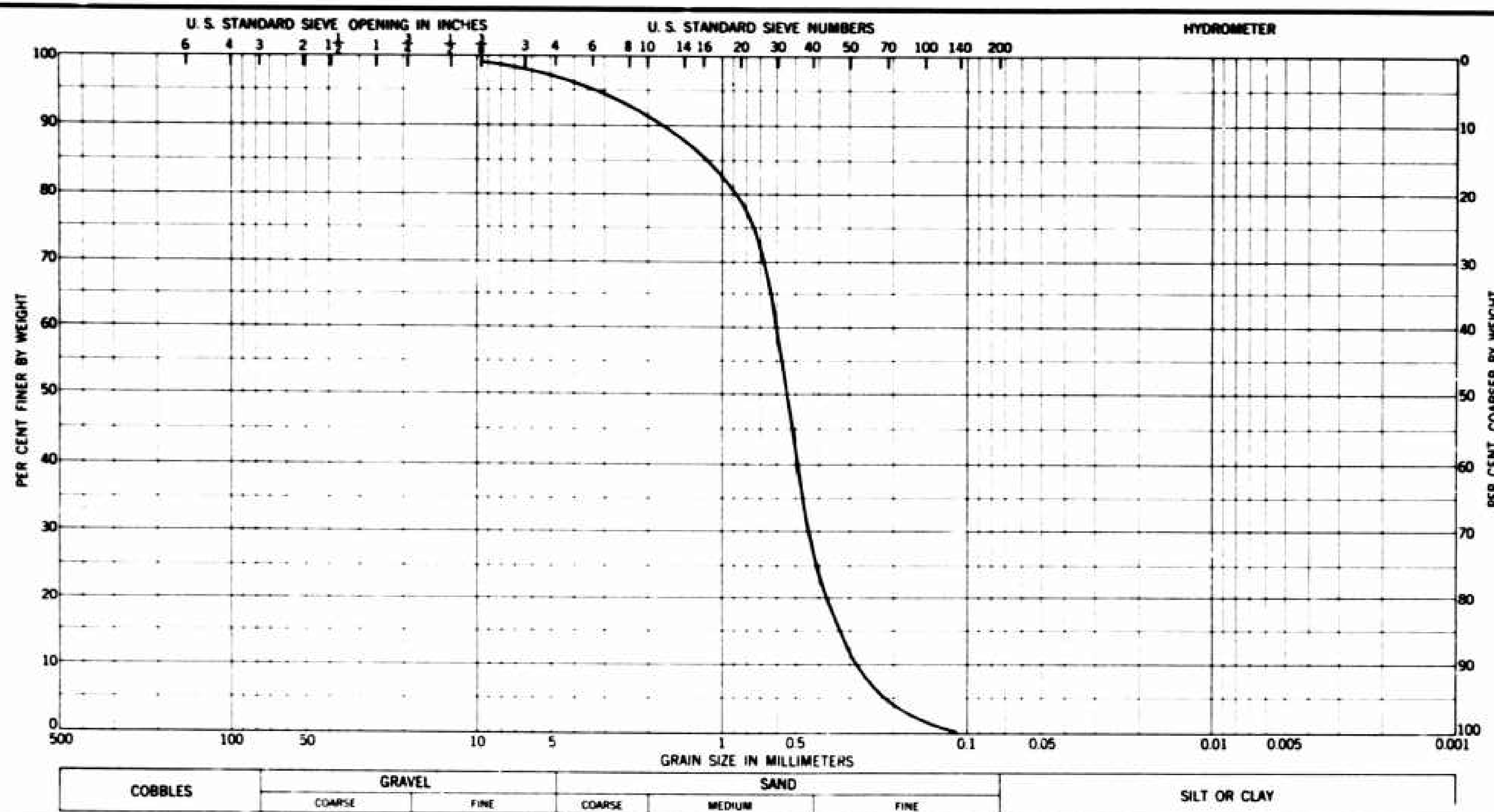


2-W-M101 TRAILER

TOTAL CONTACT AREA	62.35 SQ IN.
GROSS LOAD	3200 LB
AVG CONTACT PRESSURE	51.32 PSI
TIRE SIZE	7.50-20, 8-PR
INFLATION PRESSURE	55 PSI

VEHICLE LOADING DATA
M54, 5-TON, 6X6 TRUCK AND 2-W-M101, 1-TON TRAILER

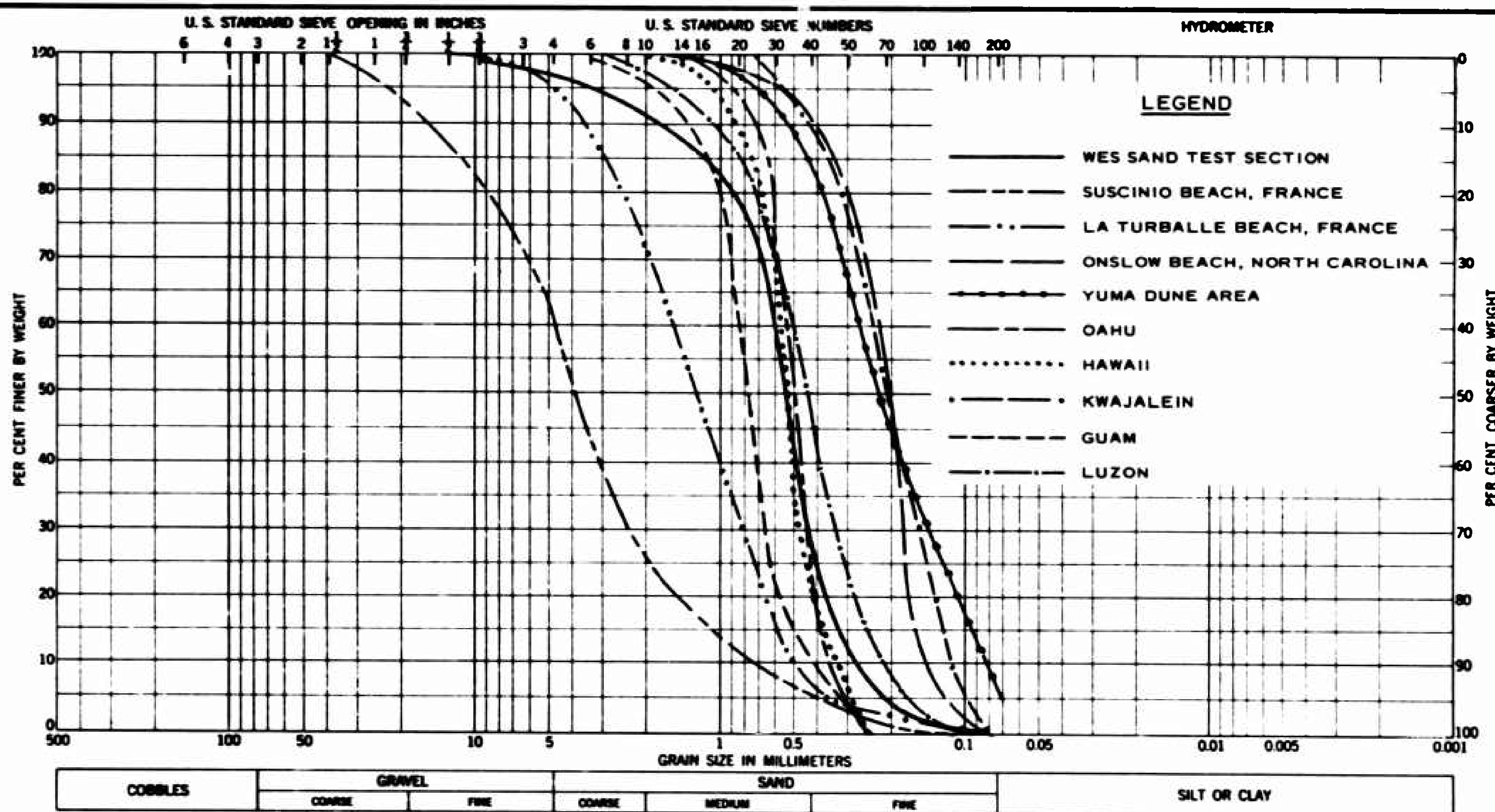
PLATE 4



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
	0 - 30"	SAND (SP) (NONPLASTIC)				

GRADATION CURVES

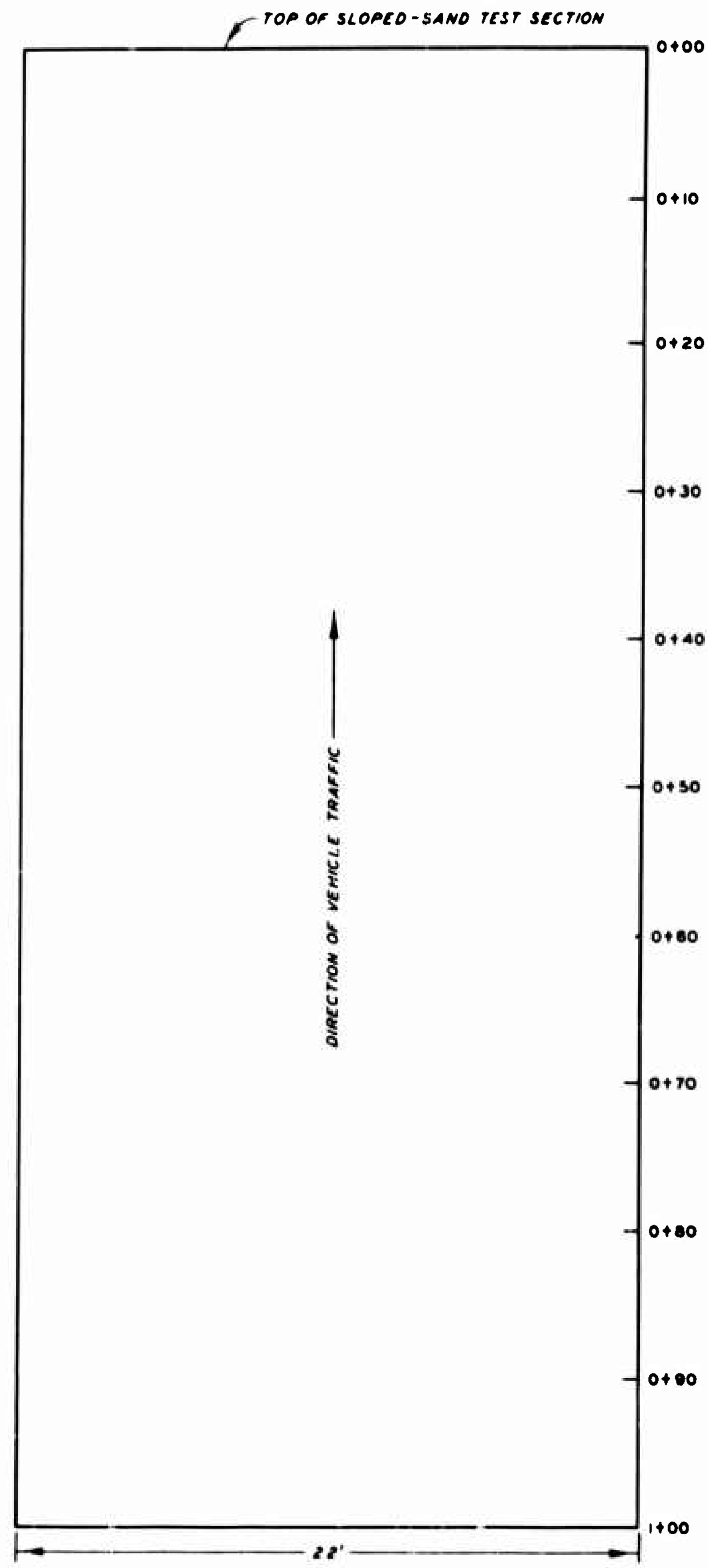
CLASSIFICATION DATA AND GRADATION CURVE OF SAND TEST SECTION



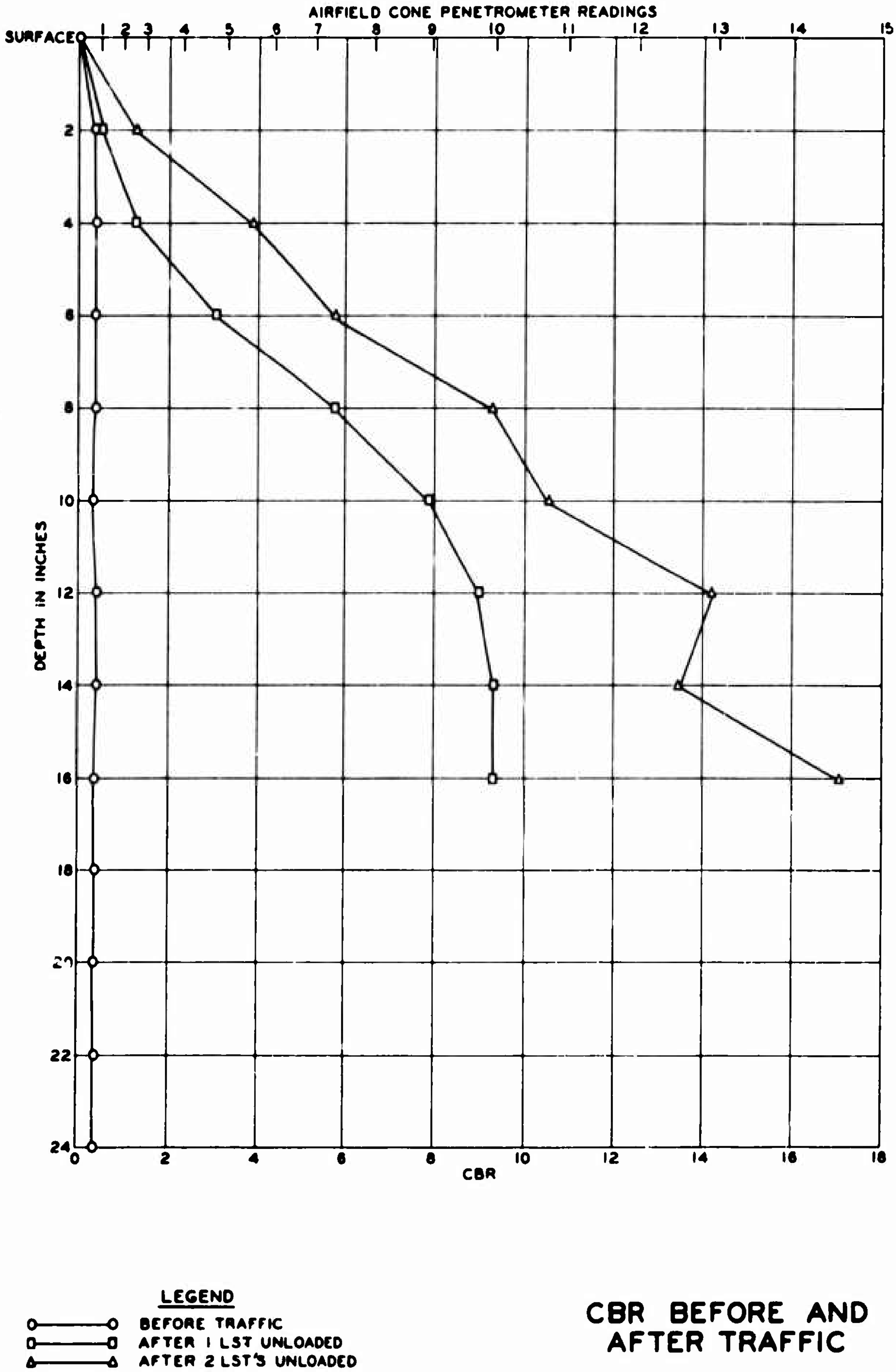
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

GRADATION CURVES

COMPARISON OF GRADATION CURVES
OF SAND BEACHES AND WES SAND
TEST SECTION



LAYOUT OF BEACH
MAT TEST SECTION

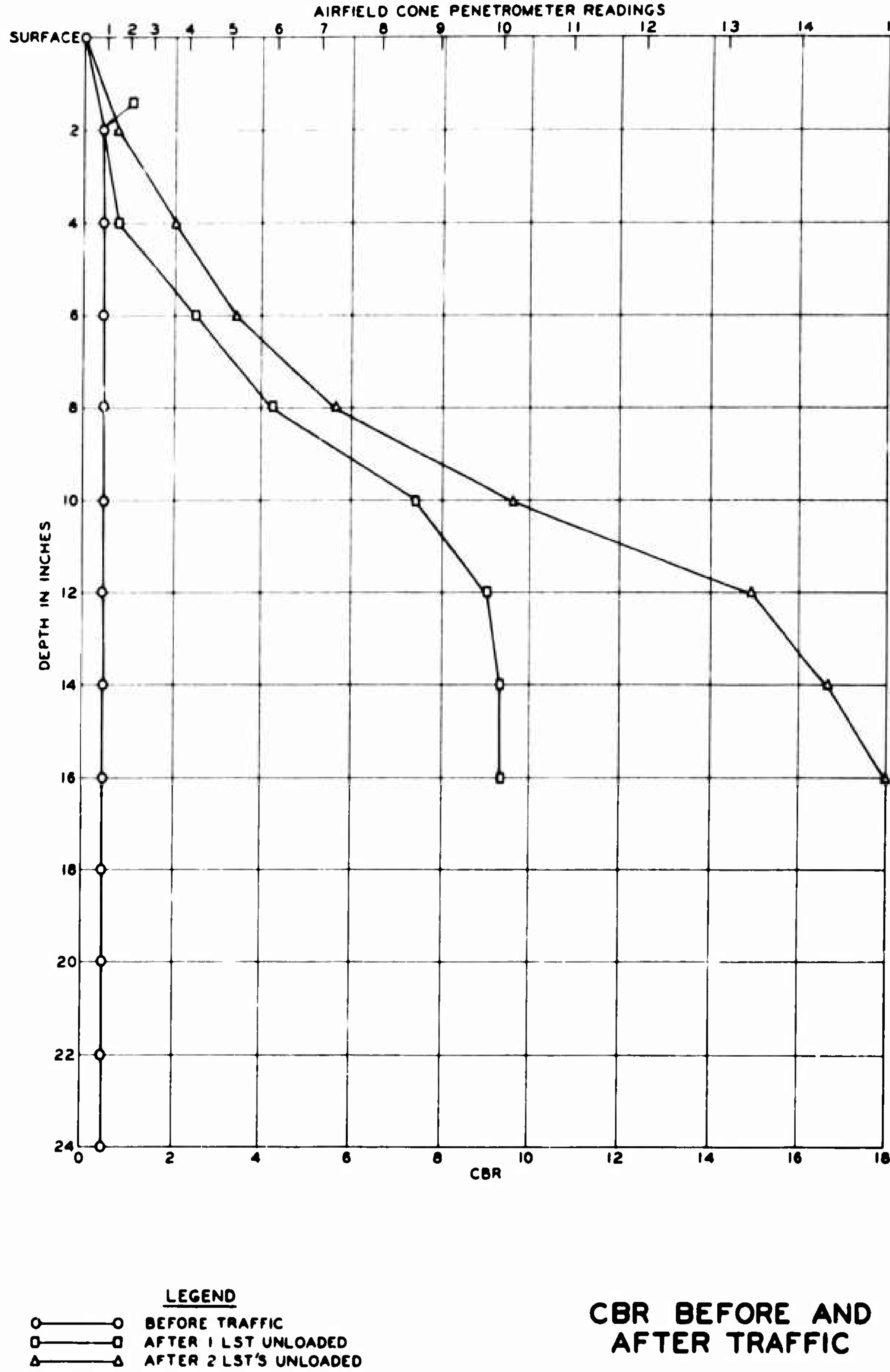


CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

TEST ITEM 1

STATION 0+25

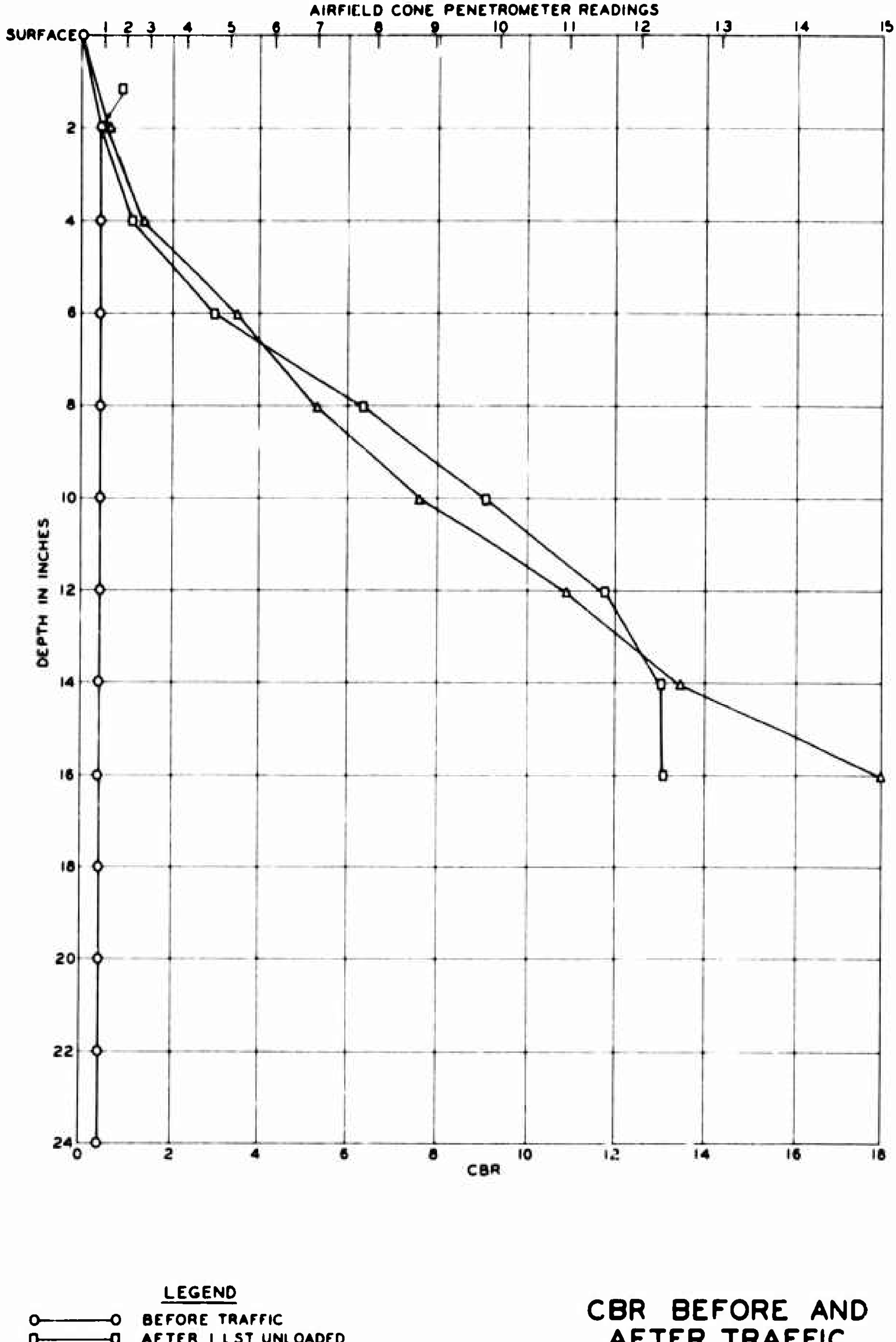


CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

TEST ITEM 1

STATION 0+50



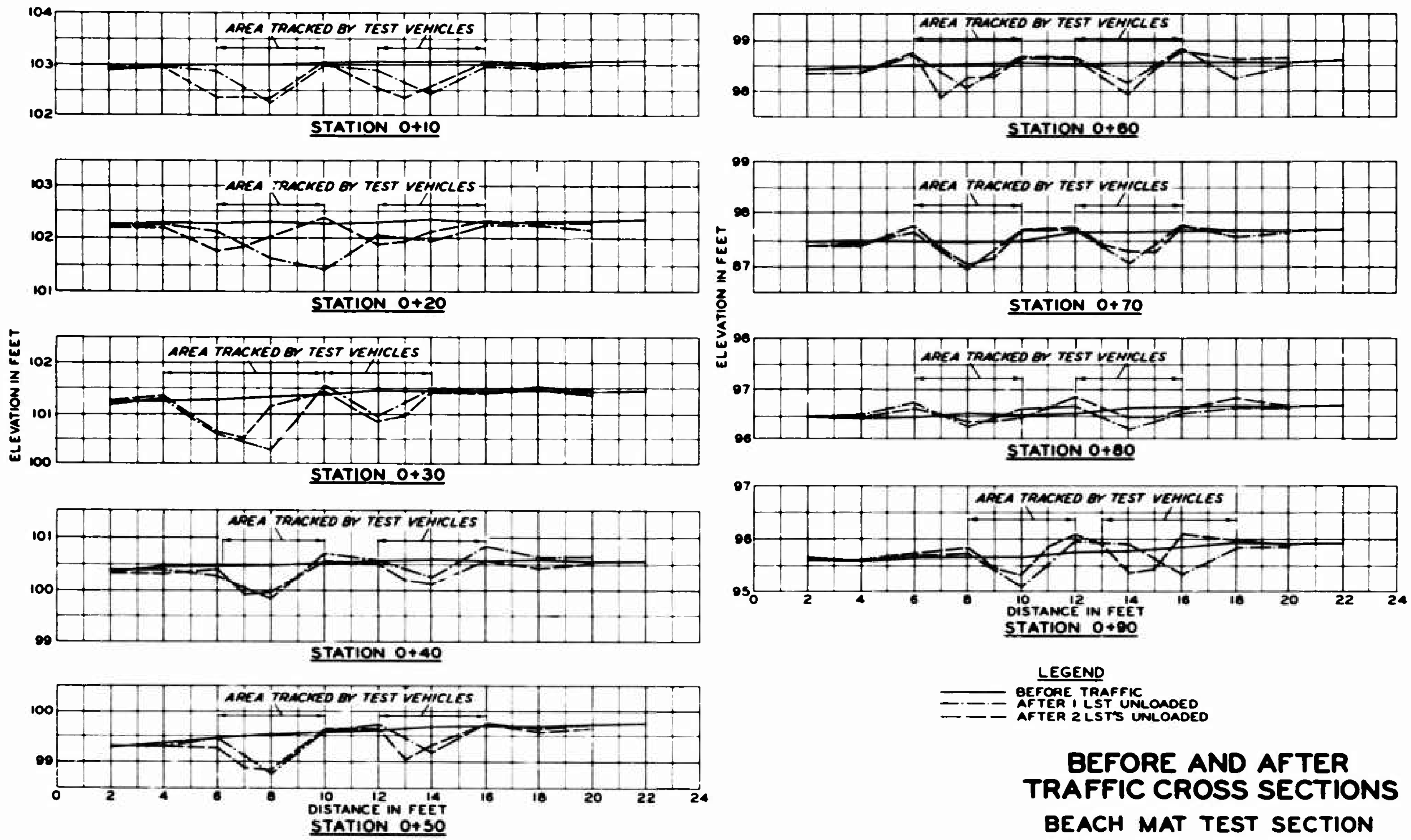
CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

TEST ITEM 1

STATION 0+75

PLATE 10



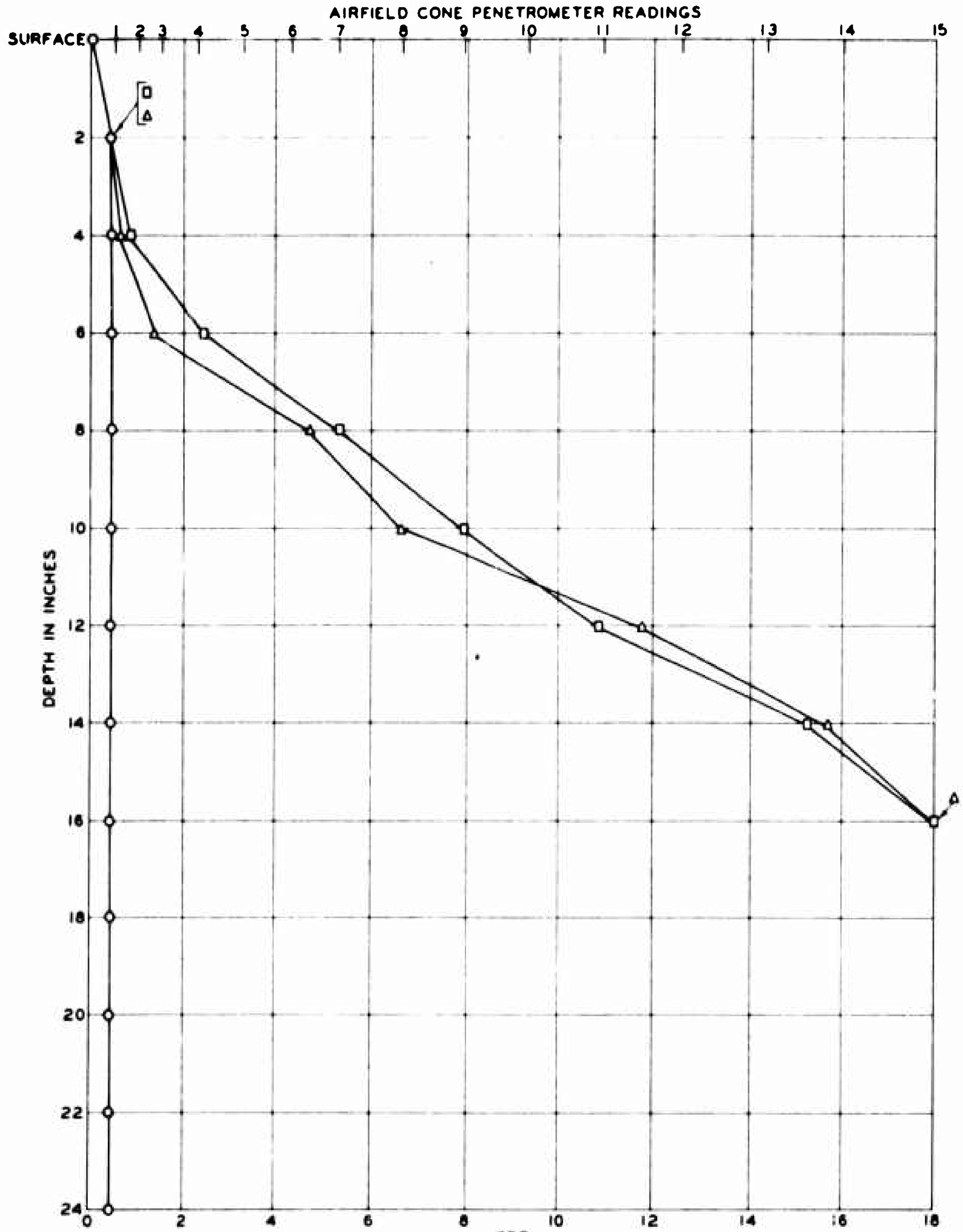
BEFORE AND AFTER TRAFFIC CROSS SECTIONS

BEACH MAT TEST SECTION

TEST ITEM I

STATIONS 0+10 THROUGH 0+90

PLATE II



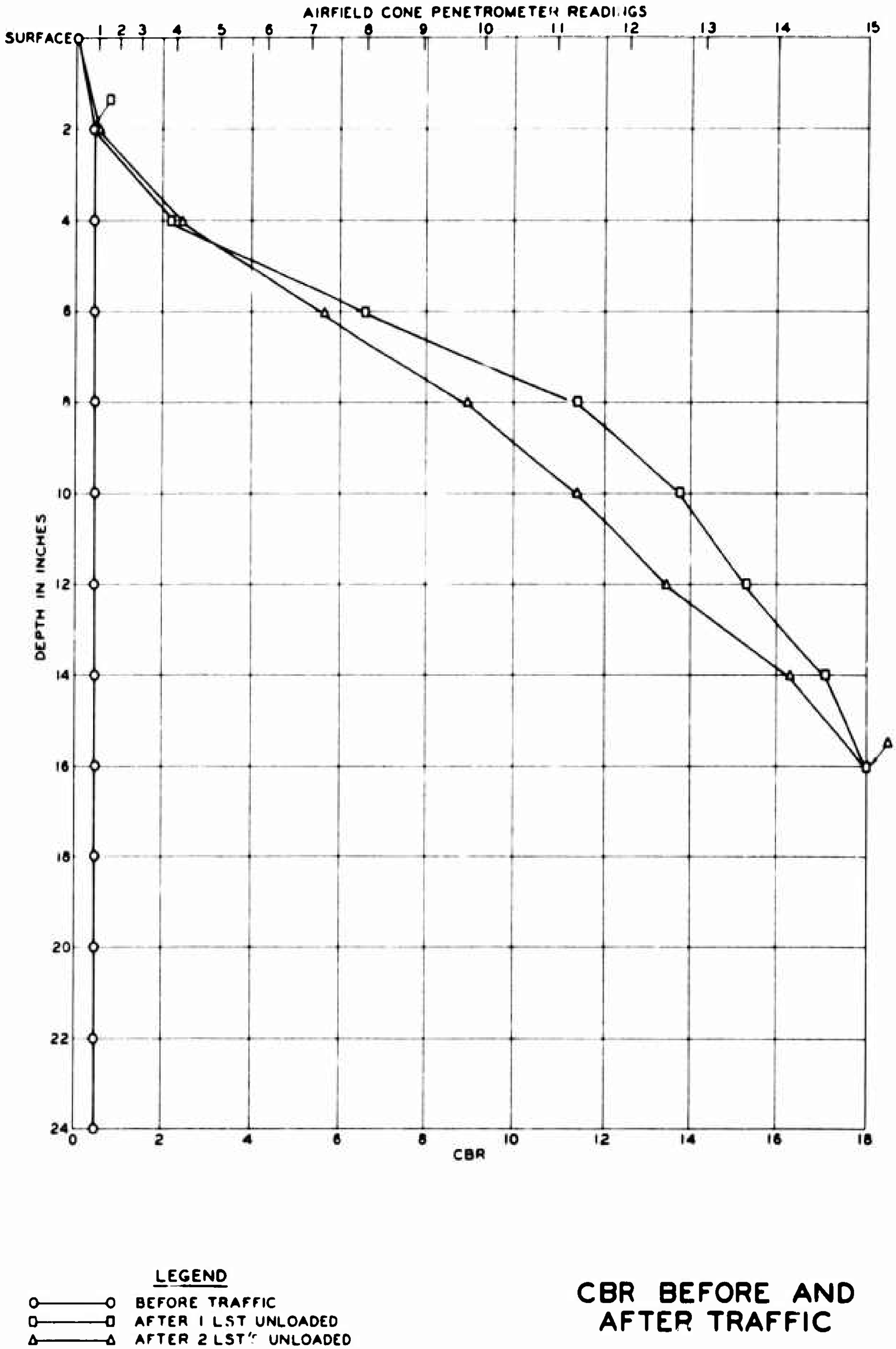
LEGEND
- BEFORE TRAFFIC
- AFTER 1 LST UNLOADED
- AFTER 2 LST'S UNLOADED

CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

TEST ITEM 2

STATION 0+25



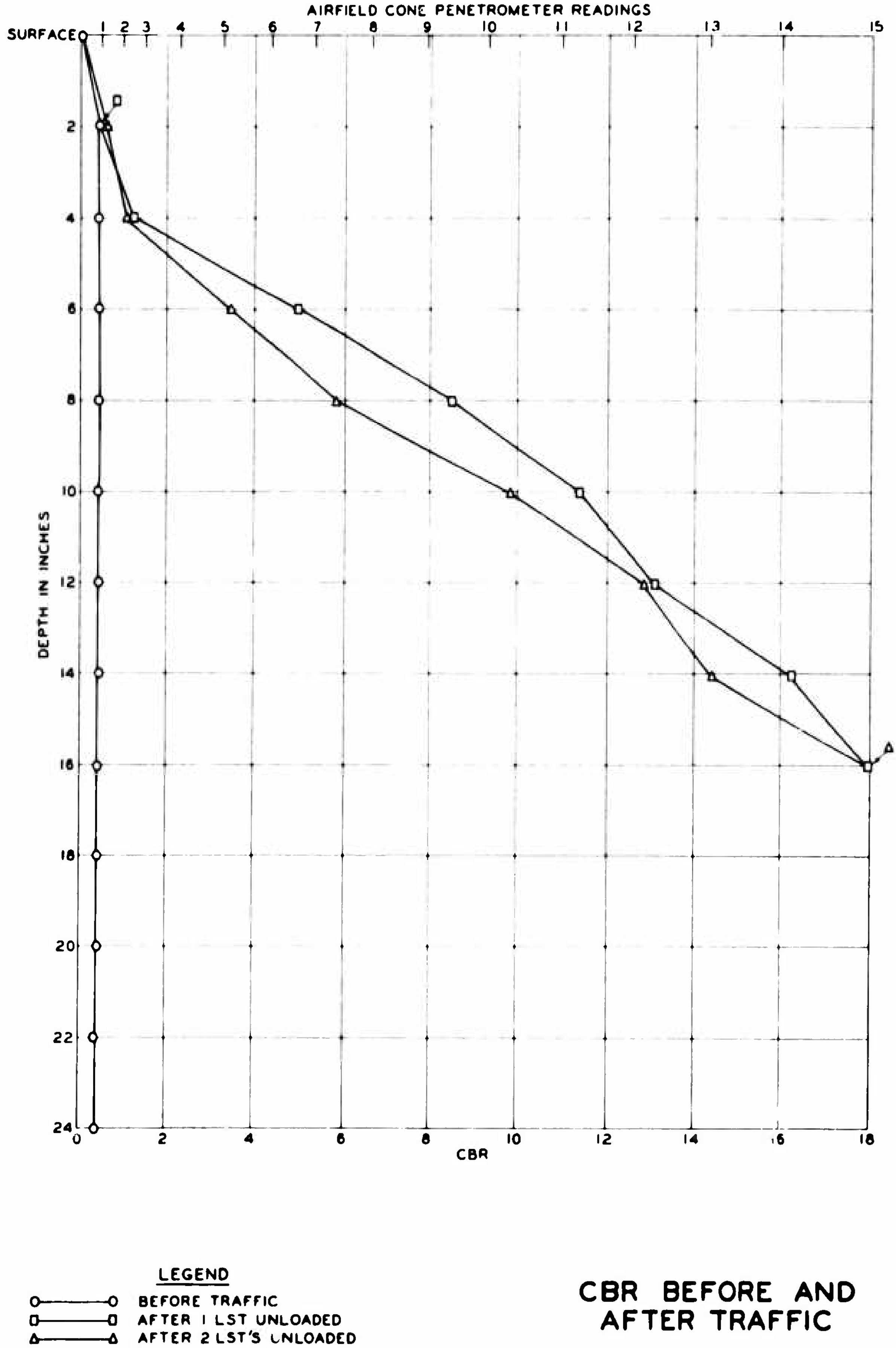
CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

TEST ITEM 2

STATION 0+50

PLATE 13



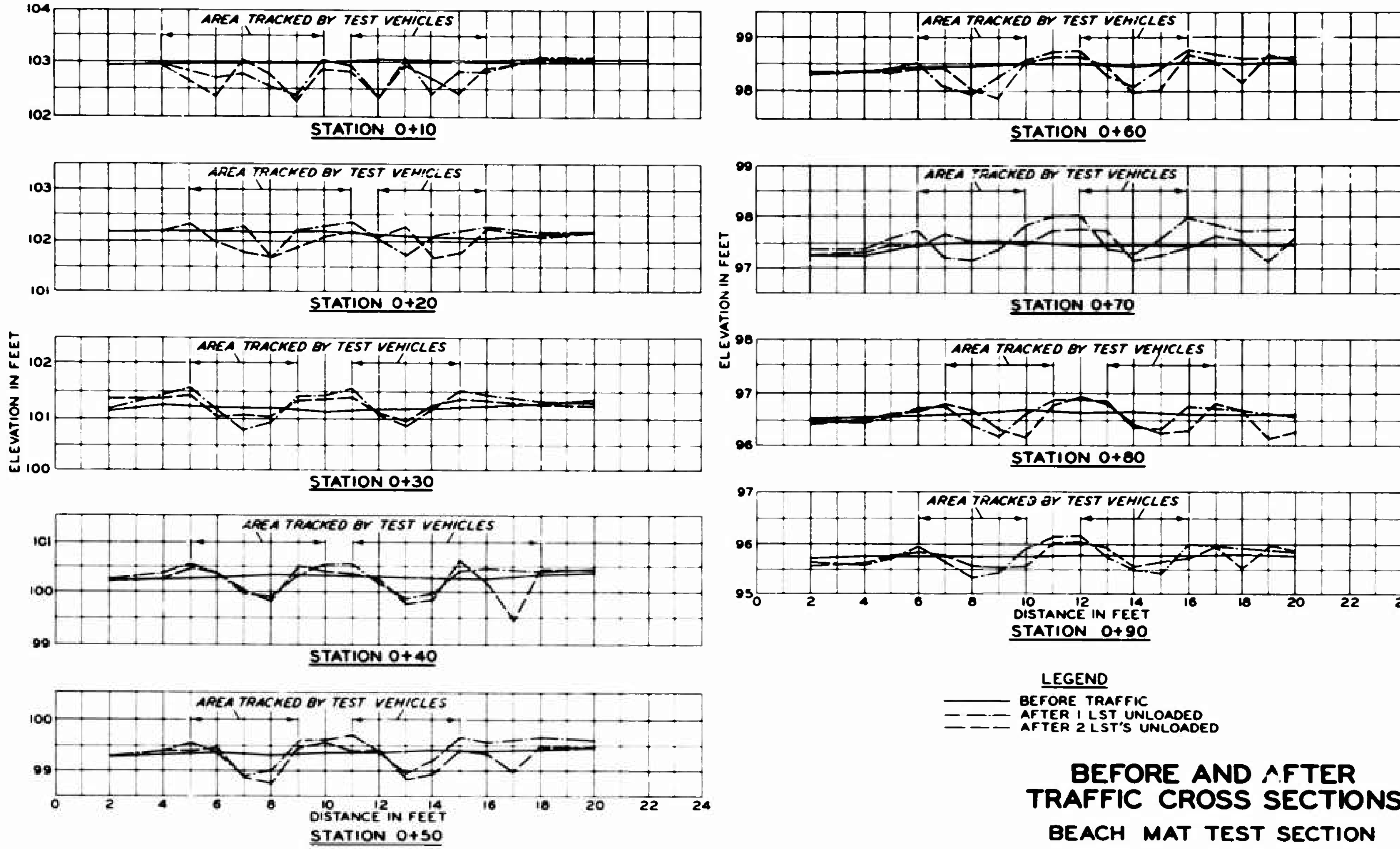
CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

TEST ITEM 2

STATION 0+75

PLATE 14

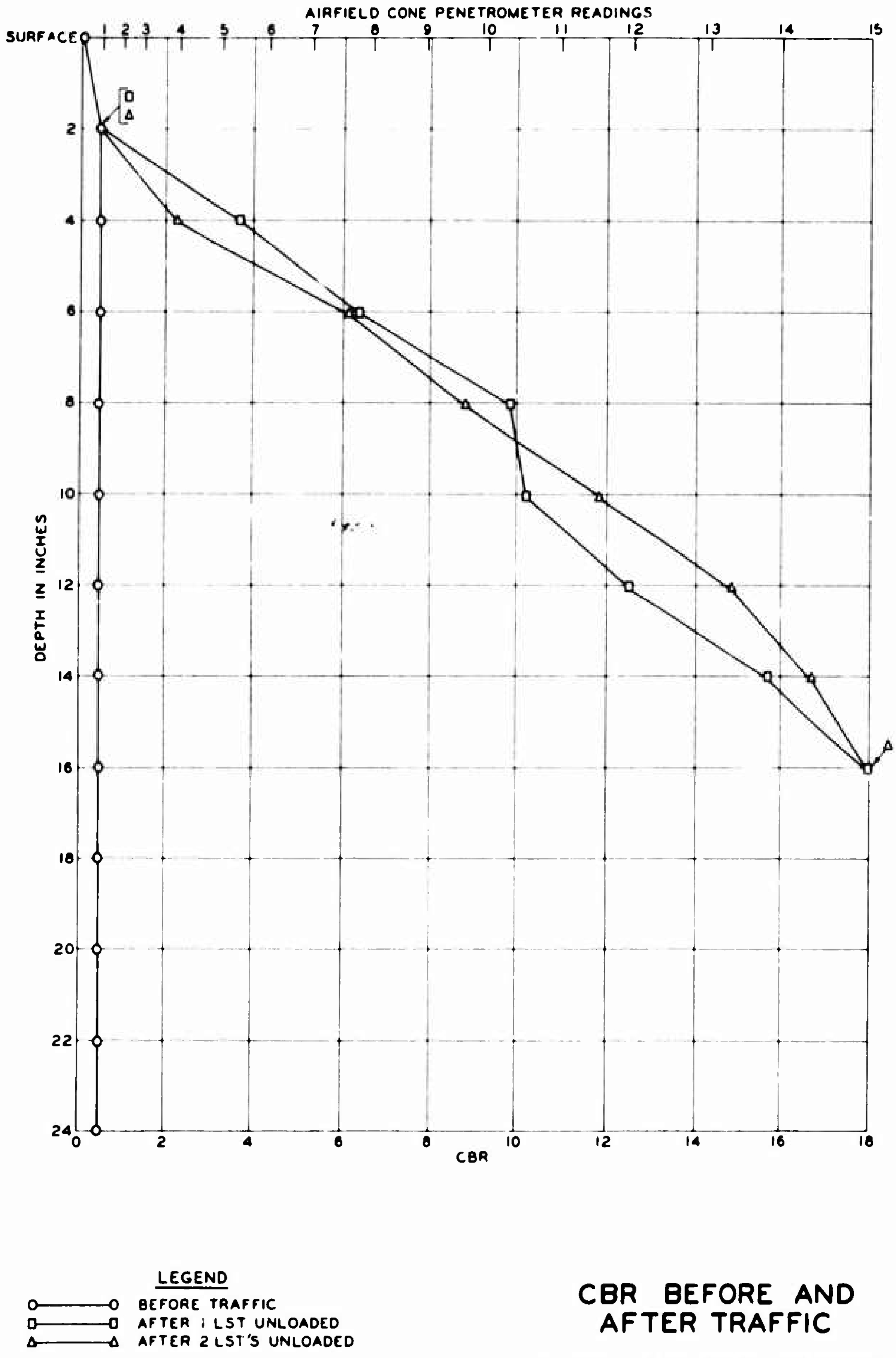


BEFORE AND AFTER TRAFFIC CROSS SECTIONS

BEACH MAT TEST SECTION

TEST ITEM 2

STATIONS 0+10 THROUGH 0+90

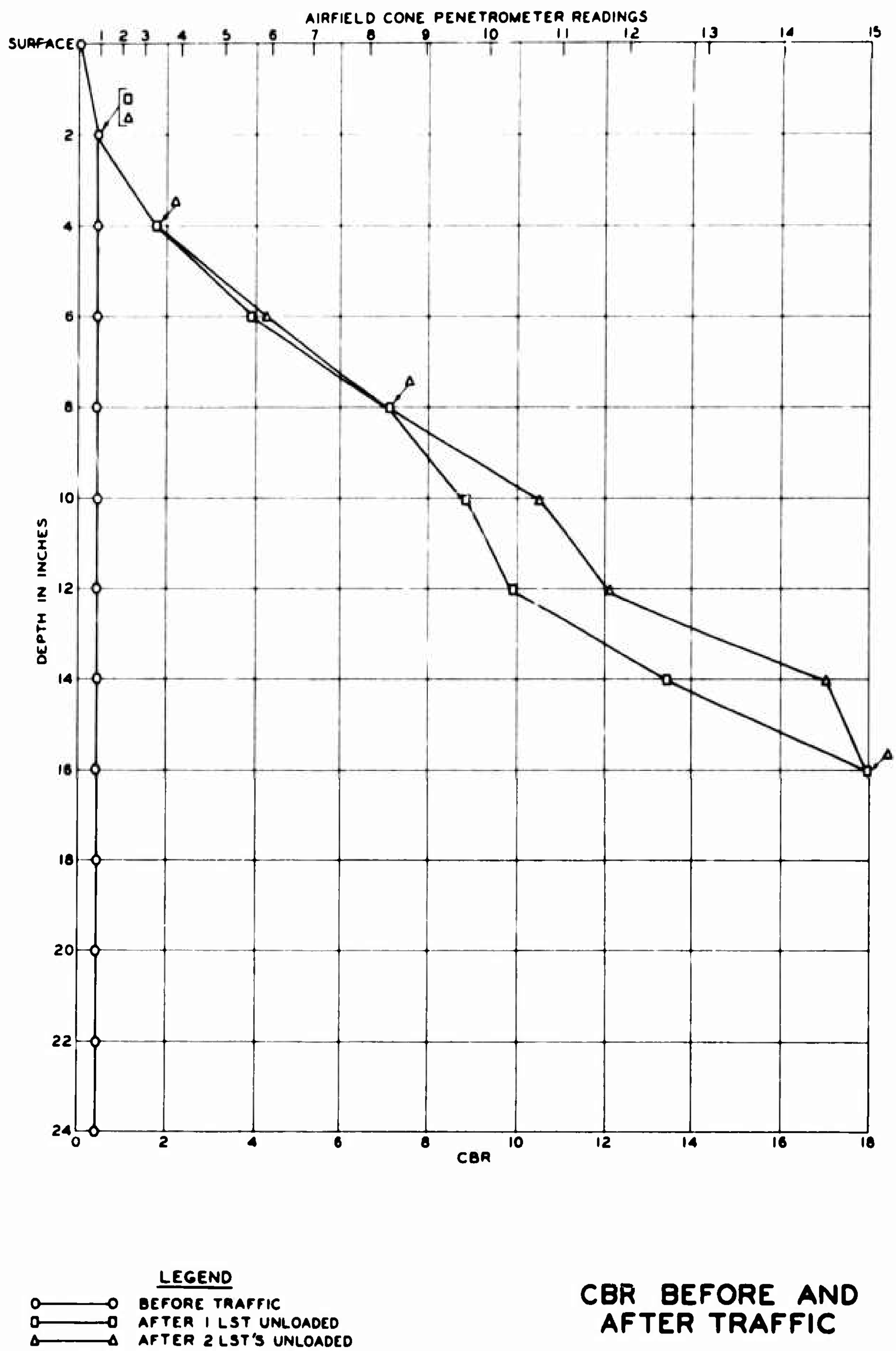


CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

WOVEN WIRE MAT

STATION 0+25

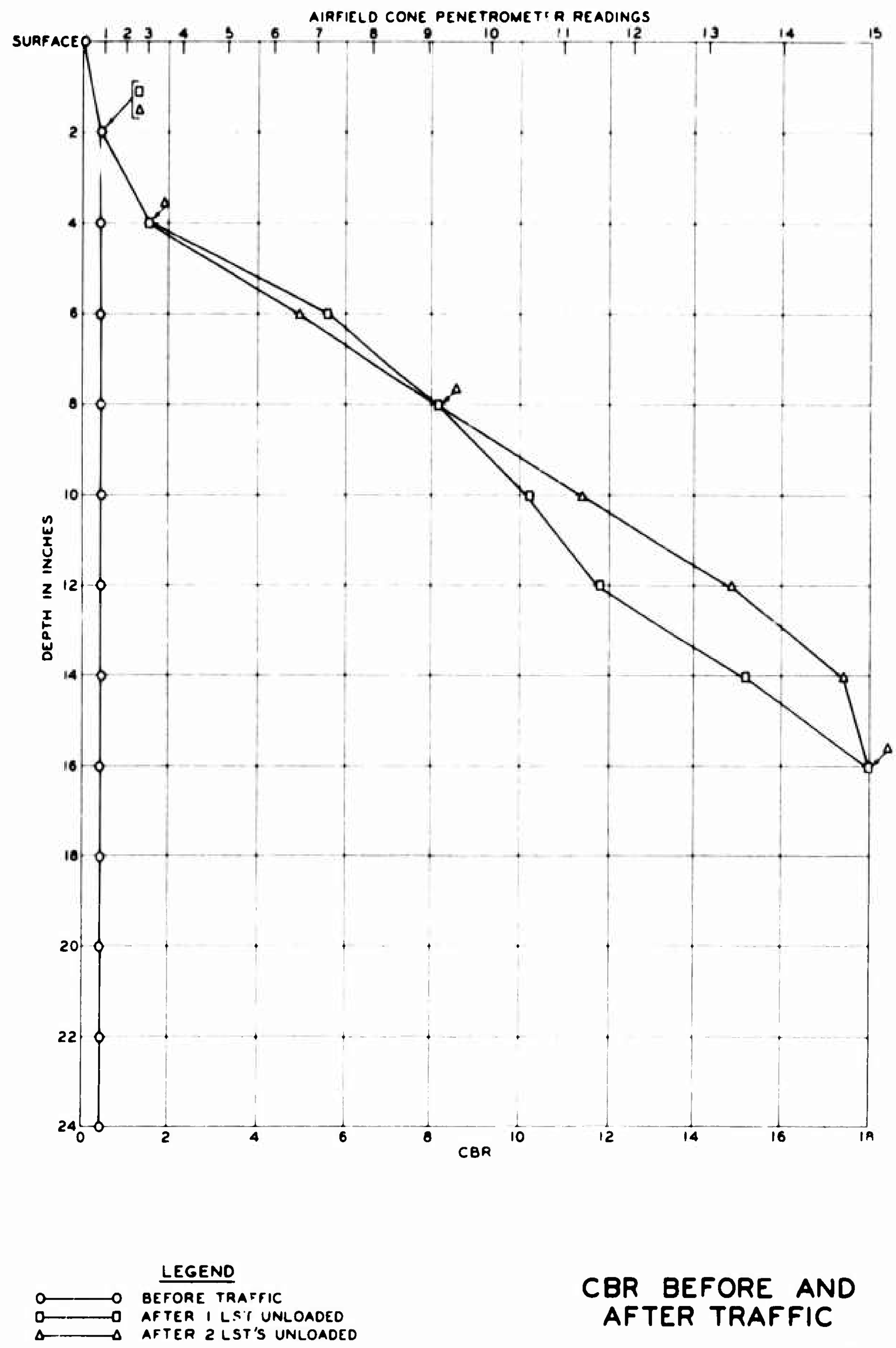


CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

WOVEN WIRE MAT

STATION 0+50

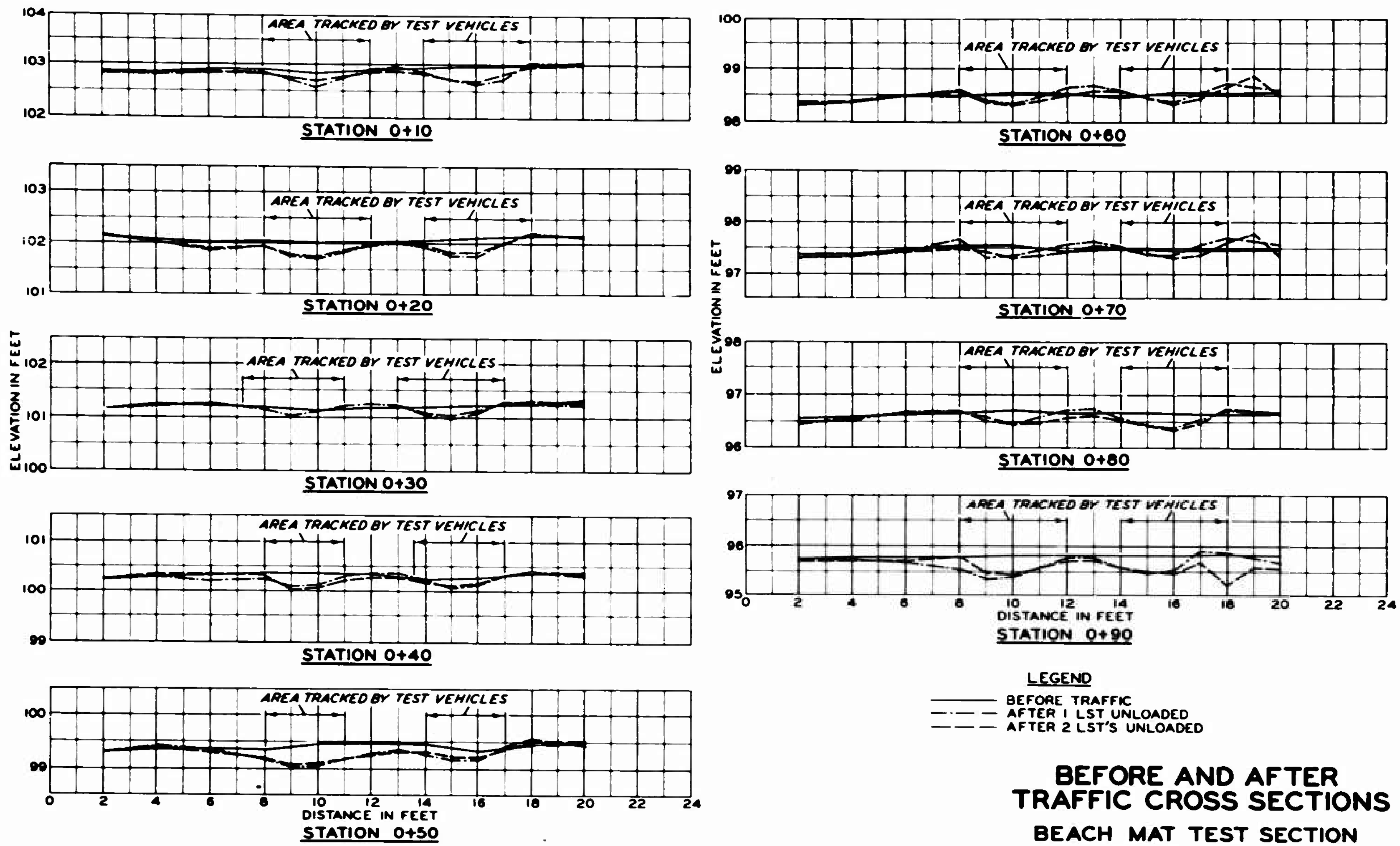


CBR BEFORE AND AFTER TRAFFIC

BEACH MAT TEST SECTION

WOVEN WIRE MAT
STATION 0+75

PLATE 18



BEFORE AND AFTER TRAFFIC CROSS SECTIONS

BEACH MAT TEST SECTION

WOVEN WIRE MAT

STATIONS 0+10 THROUGH 0+90

PLATE 19